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Performance of Joint Admission and Power Control Algorithms for Cognitive Radio CDMA Networks in Shadowed Environment

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Abstract—Cognitive radio network maximizes number of secondary users (SUs) without affecting the service of primary users (PUs). Admittance of SUs is not only affected by the path loss but also log-normal shadowing. In this paper, we have carried out the simulation study of joint admission and power control (JAPC) algorithms: JAPC-MRER and JAPC-MSSRA in presence as well as absence of log-normal shadowing. Combined effect of path loss and log-normal shadowing on total secondary revenue and blocking probability is presented. Comparison between two algorithms for shadowing and non-shadowing cases has been done on basis of different metrics.

Keywords-Cognitive Radio Network; Admission and power control; CDMA

I. INTRODUCTION

The rapid growth in wireless services over the past some years have created a huge demand for wireless communication applications. Due to which the supply of available radio frequency spectrum is often described as being in a state of shortage. Whereas demand for spectrum in the most useful frequencies exceeds supply, some statically allocated spectrum bands experience low utilization. To address this issue, Cognitive Radio (CR) [2, 6] has been introduced. CR is capable of exploiting unused or lightly used spectrum by introducing secondary users (SUs) which sense and access the unused or underused part of licensed spectrum and increases the efficiency of spectrum utilization. CR accommodates both primary uses (PUs) and secondary users at same time with the constraint on SUs that they will not affect the quality of service (QoS) of PUs beyond an allowed limit.

In past, some works have been carried out on joint admission control and power allocation problem in Cognitive Radio CDMA networks. In [4], L.Zhang proposed a Minimal SINR removal algorithm (MSRA) to search optimal set of SUs. MSRA outperforms the game theory approach in [3]. But it is assumed that a single PU is present in the system and only path loss was considered which is practically not possible.

Contribution of the paper: Xiang proposed a joint admission and power control scheme using a minimal revenue efficiency removal (JAPC-MRER) algorithm to search optimal SUs to maximize the secondary revenue [1]. However, they studied performance of JAPC algorithms for a system model considering only path loss. Whereas long term shadow fading is always present along with path loss in wireless system. In [7], performance of JAPC-MRER, JAPC-MSSRA as proposed by us and JAPC-Random was investigated. Data transmission rate (DTR) was chosen randomly at the beginning of iteration. i.e., DTR was chosen same for a number of iterations in the simulation. Here, we keep DTR inside the main loop, so that DTR is chosen randomly in all iterations in our simulation.

II. SYSTEM MODEL

We consider an underlay system model represented by Cognitive Radio CDMA networks consisting of Npu number of primary users (PUs), Nsu number of secondary users (SUs) with a base station (BS) as shown in Fig. 1. This Cognitive radio CDMA networks use CDMA as multiple access mechanism. Service provider gets the revenue from the total payment made by admitted SUs.

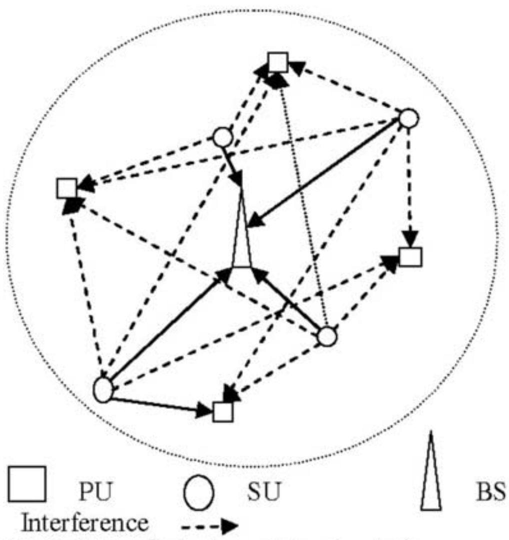


Fig 1: The cellular layout for simulation

III. CONSTRAINT ANALAYSIS

A. *Interference power:*

PUs are assumed in receiving mode and SUs are trying to transmit data in uplink to the BS [1, 7]. Hence, PUs will sp ij 10

(2)

$h = * 10$

ij n

sp

(d)

ij

G_i^s, G_j^p denote antenna gain of SU i and PU j respectively. d_{ij}^{sp}, n denote distance from SU i to PU j and path loss factor respectively. î (decibel) has a normal distribution with zero mean and standard deviation of ó which is independent of distance and ranges 5 ~ 12 dB with a typical value of 8 dB. The inference power at PU j due to SU i is $ô_{ij} = h_{ij}^{sp} * P_i^s$ (3)

B. QoS Requirement:

According to Shannon's channel capacity formula $ë_i = B \log_2 (1 + SINR_i^s)$ (4)

also receive some power from SUs. This accumulated power at PUs is interference power.

Let *Tj* denote the interference power received by PU j from all other SUs.

N

su

$T_j = “ h_{ij}^{sp} * P_i^s$ (1) i=1

Where h_{ij}^{sp}, P_i^s and N_{su} denote power attenuation from SU i to PU j, transmission power of SU I and Number of SUs respectively.

$G^s * G^p î ij^{sp}$

B is the uplink bandwidth, $SINR_i^s$ represent uplink SINR of SU i measured at BS and $ë_i^s$ uplink maximum data transmission rate (DTR). Let *I* denote the accumulated interference at the BS caused

s

by all SUs

n

s

sb s

$I_s = “ h_i * P_i$ (5) i=1

Signal strength due to SU i at BS is

s sb s

$S_i = h_i * P_i$ (6) We can calculate the uplink SINR of SU i as

$h^{sb} * P^s h^{sb} * P^s$

$SINR^s = {}_{ii} = {}_{ii}$ (7)

i n sb s sb s

$N_o + “ s_{j=1,j`”i} h_j * P_j N_o + I_s “ h_i * P_i$

h_i^{sb}: The power attenuation from SU i to the BS

$h_i^{sb} = \frac{G_i * G}{n} * 10^{10}$ (8)

sb

(d)

i

G^b: the antenna gain of the BS. d_i^{sb}: the distance SU i to the BS

C. Power control:

Let P_i^{min} (i “ N_s^{new}) denote the minimum transmission power of SU i to achieve the required minimum SINR,

s min

$SINR_i$. The ratio relationship of P_i between all SUs can be represented in the following equation [1]:

min min min

$P_1 : P_2 : K : P_n = y_1 : y_2 : K y_n$ (9)

SS

Where,

$y_i = (d_i^{sb})^n$,”i “ N_s^{new} (10) sb

1

$G_i * G * (1 +_s)$ ëi “1

B

2

And, $y_{max} = max\{ y_i \mid “i “ N_s^{new} \}$ (11) Power for SUs is calculate as

áP^s

$P_i^{min} = {}^{max} y$ (12) $^y max$

±: Power scaling factor (±”*(0,1)*)

difference of total interference power at PU j and its threshold is given as Õ$_j$ = “ ô$_{ij}$ “Ã$_j$ (13) i”N_s^{new}

Ã$_j$: Interference threshold.

If Õ$_j$ is greater than 0, the interference power received by the PU j is greater than its threshold. So system needs to remove SUs. Otherwise the PU j can continue with all available SUs.

For solving the optimization problem revenue efficiency factor is used. It finds the SUs with high revenue and also low interference [1].

$$e_i = {}^{r_i} \text{“}i\text{ “ } N_s^{new} \quad (14) \quad \text{“ } j\text{”} N p^{new\,\tilde{O}} \hat{j}^{\hat{o}} ij$$

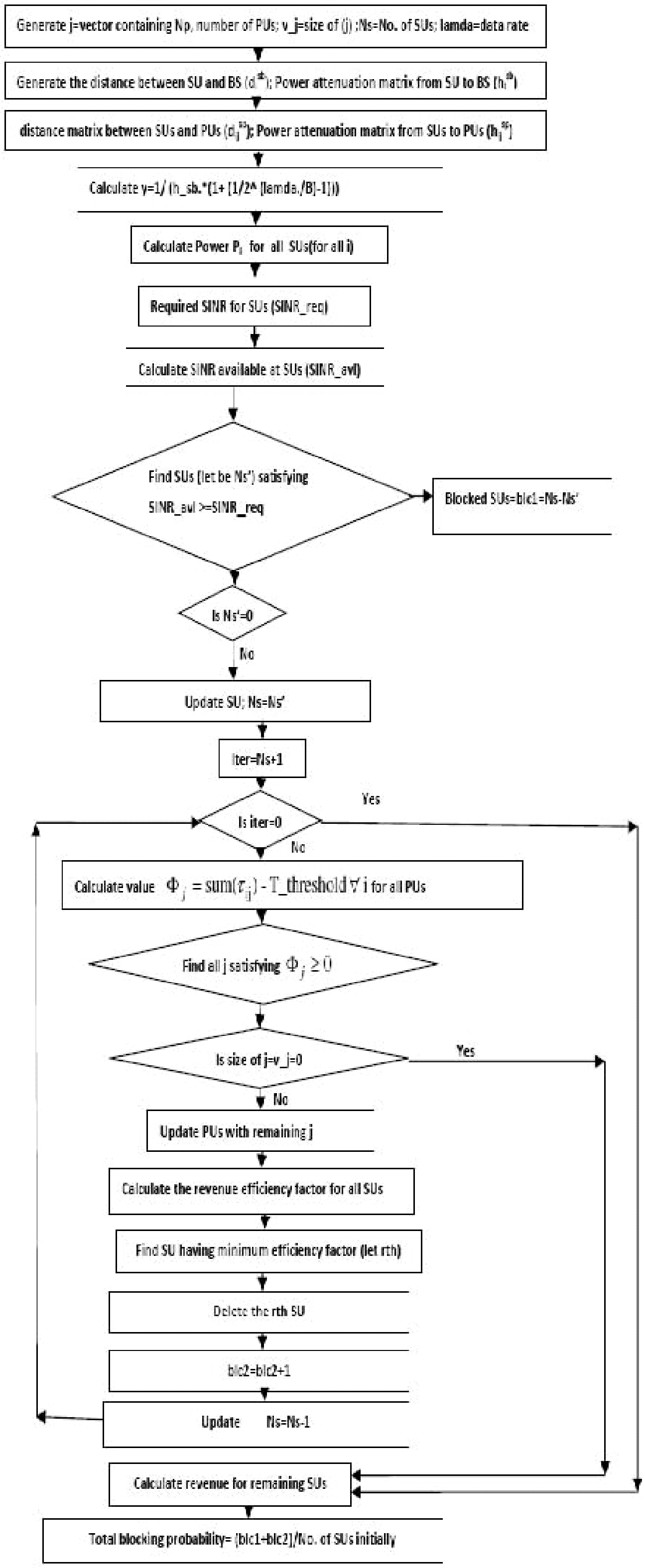
N_s^{new} : Possible set of admitted SUs.

N_p^{new} : Valid set of PUs.

IV. FLOW CHART AND SIMULATION MODEL

The simulation is developed in MATLAB. The PUs and SUs are present in the hexagonal cell approximated by a circular one with radius R. Distance and angle of PUs and SUs with respect to BS are generated randomly as per uniform distribution. Then, we calculate the distance between PUs and SUs [5]. DTR is randomly chosen from a set of values with equal probability. The users are power controlled by the BS as in (12). The link gain is according to (2) and (8). A fixed value for all antenna gains at PUs and SUs are considered. á is assumed to be 1 (one). The numbers of SUs, PUs and interference threshold are changed according to the requirement for simulation. Noise term in the SINR expression has been neglected in our simulation.

Flowchart of algorithm:



The above flowchart describes our simulation model. In our algorithm, we check if QoS of all SUs are getting satisfied or not for each iteration. On the basis of this, a decision is made regarding removal of a SU from the list.

V. RESULTS AND DISCUSSIONS

In this section, the performance of joint admission and power control scheme JAPC-MSSRA is investigated along with the JAPC-MRER [1] in presence of log-normal shadowing. We also compared the revenue as well as blocking probability of both algorithms in presence of lognormal shadowing with that of without shadowing.

A. Simulation setup:

In our assumed model, one cell is generated with a radius of 1000m having BS at centre of cell. The distance and angle between SUs or PUs and BS are randomly generated from 100m to 1000m and [0,2Ï] respectively. Without loss of generality, we assume all antenna gains of SUs, PUs, and the BS as 1. The uplink channel bandwidth B is set as 5MHz. The Data Transmission Rate (DTR) of a SU is randomly chosen from {8, 32, 128} kbps. The revenue obtained from SUs depends on the DTR. The Secondary Revenue for 8 kbps DTR is r = 1, for 32 kbps r = 4 and for 128 kbps r = 16. The path loss factor n is set as 4 and value of î is set as 8. The power scaling factor is set as one.

B. Performance evaluation:

a). With varying number of SUs:

Fig. 2 and Fig.3 show secondary revenue and blocking probability respectively with various numbers of SUs. In this example, the number of PUs is fixed at 6. The interference power threshold is set at -100dBW for all PUs. The number of SUs varies from 15 to 50.

Secondary revenue in terms of SUs

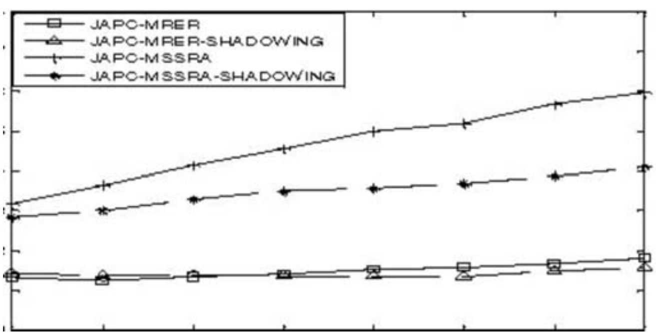


Fig 2: Blocking Probability Vs Secondary Users

In Fig.2, blocking probability of JAPC-MSSRA is more than that of JAPC-MRER. It is due to the fact that the MRER removes the SUs on basis of revenue efficiency factor which leads to remove a user having more signal strength but low revenue, thus a strong source of interference is blocked. It results in overall reduction of interference on PUs by a considerable amount. So, more number of SUs can be accommodated. Whereas MSSRA removes SUs on the basis of minimum signal strength, equation 14) decreases considerably. Thus interference power produced by SUs starts dominating the revenue efficiency factor. So some SUs having moderate revenue are also rejected along with SUs having less revenue which leads to decrease in secondary revenue in presence of shadowing. b). With varying number of PUs:

therefore it has to remove more number of SUs to reduce the interference by the same amount.

In case of shadowing, there is a significant improvement in the blocking probability for MSSRA as compared to MRER. It is due to the reason that power received at PUs from all SUs will be reduced compared to the case where only path loss was considered. So interference power for PUs will be reduced. As the allowed interference power is fixed, system can allow more number of SUs. Thus for the same number of initial SUs, less number of SUs are blocked compared to only the path loss case. For the same reason, there is improvement in blocking probability of MRER also in presence of shadowing but improvement is not significant.

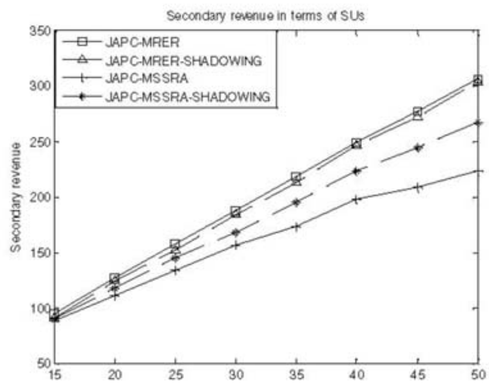


Fig.4 shows the plot of blocking probability versus the number of PUs. Number of SUs is fixed at 50. When the number of PUs is high, the SUs are present near to many other PUs. So the SUs create high interference to other PUs. To satisfy the QoS of large number of PUs more numbers of SUs are rejected by system. Thus blocking probability increases with increasing number of PUs. JAPC-MRER gives the lowest blocking probability due to its balance

between the revenue and the interference. JAPC-MSSRA rejects SU based on its minimum signal strength, so relatively more numbers of SUs are rejected. Shadowing

Secondary revenue

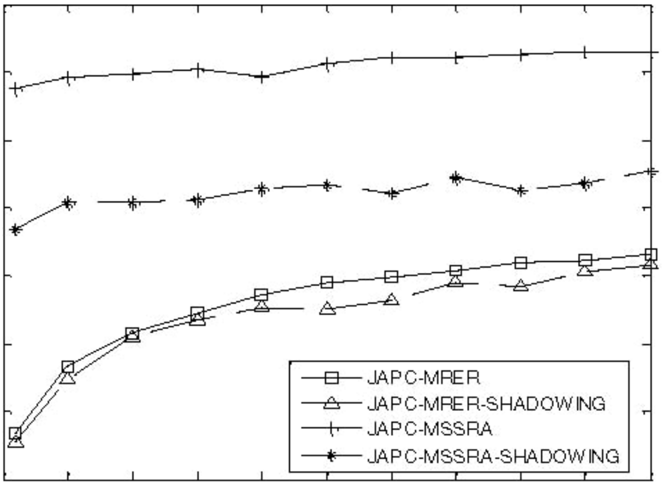


Fig 3: Secondary revenue vs. Secondary Users

almost similar for both algorithms because interference 0.1 powers at all PUs are too small to exceed the threshold. JAPC-MSSRA has lower revenue than JAPC-MRER as it removes the SUs on the basis of signal strength without caring about revenue resulting in removal of some users
Fig

As more numbers of SUs are accepted in presence of shadowing, revenue of MSSRA is more than that in absence 350 of shadowing. In case of MRER, rejection of SUs depends on both, secondary revenue as well as interference power. A PU is said to be in danger zone if total interference power experienced by it is more than maximum allowed power, *i.e.*, interference threshold. We consider a set of PUs

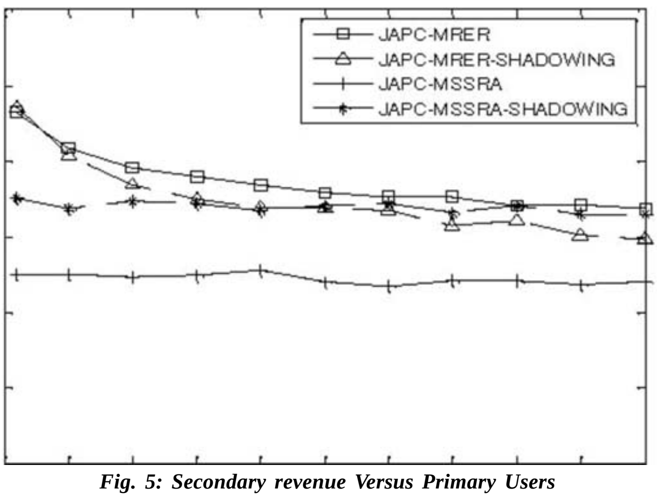


Fig. 5: Secondary revenue Versus Primary Users

Secondary revenue decreases as blocking probability increases. JAPC-MRER gives more secondary revenue than that of JAPC-MSSRA because MRER is considers both revenue and interference while blocking the SUs whereas MSSRA care about only signal strength. In case of shadowing, blocking probability decreases considerably for JAPC-MSSRA, that is why its secondary revenue is much improved. In case of JAPC-MRER, shadowing does not improve its blocking probability substantially due to optimum nature of MRER. As the number of PUs, which are in danger zone decreases the revenue efficiency factor is dominated by interference caused by SU instead of secondary revenue. So the ratio calculating revenue efficiency factor gives low value for moderate revenue and high interference power. This results in removal of some SUs contributing good revenue. So, secondary revenue in this case is lesser than that of without shadowing case. c). With varying interference threshold:

In this case, we have fixed the number of PUs and SUs at 6 and 50 respectively. Average revenue and blocking probability is calculated for different values of interference power threshold.

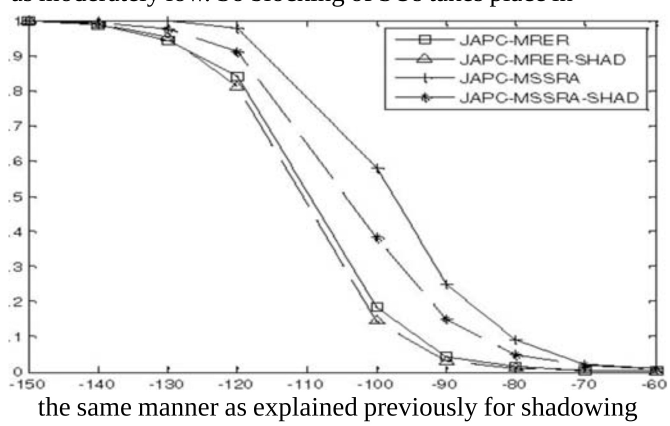
Blocking Probability in term of interference theshold

more than that in JAPC-MSSRA as former one optimizes revenue. When the interference threshold is greater than 140dBW and less than -60dBW the secondary revenue is monotonically increasing and blocking probability is monotonically decreasing with the increase in interference threshold.

In case of shadowing, performance of JAPC-MSSRA is better than that in without shadowing case. Response of JAPC-MRER in presence of log normal shadowing depends on the threshold power. If low interference threshold such as -140dBW is chosen the system can give permission to a few number of SUs and all other SUs are blocked. So secondary revenue obtained is very low. When interference threshold

lies between -140dBW to -90dBW, the value of $\tilde{O}_j$,

difference of accumulated interference power at jth PU and its threshold power [13], decreases but remains positive as well as moderately low. So blocking of SUs takes place in



the same manner as explained previously for shadowing blocking probability. Whereas, in case of MRER, more number of secondary users are allowed when shadowing is considered. But secondary revenue obtained is marginally lesser than that in case of without shadowing. But overall performance of MRER is better than that of MSSRA. MSSRA may be suitable as JAPC algorithm for highly

Fig 7: Secondary revenue Vs Interference threshold

[5]
Yue Chen, Soft Handover issues in radio resource management for 3G WCDMA networks, PhD thesis, Department of Electronics

Fig.7 shows the variation of revenue with respect to the

Engineering, Queen Mary, University of London, Sep 2003.

threshold. Revenue obtained in case of JAPC-MRER is [6]

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