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Interference Model for Scheduling Algorithm in CDMA Based Cognitive Radio Network

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ABSTRACT

In this research paper Interference Model for Scheduling Algorithm in Cognitive Radio Networks (CRNs) is designed. In the advancement of 4G it plays vital role. [1]. The first phone call over a cognitive radio network was made on Monday 11 January 2010 in Centre for Wireless Communications at University of Oulu using CWC's cognitive radio network CRAMNET (Cognitive Radio Assisted Mobile Ad Hoc Network), that has been developed solely by CWC researchers Two types of CDMA based wireless networks are Cognitive radio networks (CRNs), and. Cooperative communication networks.[5] Same spectrum is shared in all instantaneous transmissions in the networks and interferes with one another In Cognitive radio, spectrum is inadequate resource in wireless communications. Currently, fixed spectrum slices are licensed to each wireless service technology. Recent studies [6] [8] have discovered that more than 80 % of spectrum is unutilized in rustic areas.

General Terms

Interference model, Cognitive Radio Network, Scheduling Algorithm.

Keywords

Equal Speed Allotment, Proportional Speed Allotment, CRN, Interference Threshold

1. INTRODUCTION

Radio Resource Management (RRM) plays imperative part in CDMA Based Wireless Networks [3]. In such a system users may transmit their signals concomitantly in the same frequency band. Each transmitter is consigned a dedicated spreading code, which can be reproduced at the intended receiver to regenerate receiver to regenerate the transmitted signal. The cross-correlation of different spreading codes is ideally zero, so that desired signal can be recovered and other interfering signals can be removed at the receiver [4]. In a practical system, the radio channel can be nonlinear and the spreading codes may not be orthogonal to one another. If additional users are there in the system and the higher power they transmit then the more interference they generate to one another. A number of novel ideas have been projected to provide more flexible and resourceful usage of the spectrum. The concept of dynamic spectrum access (DSA) or open spectrum is discussed in [9], which endeavors to dynamically manage spectrum access and spectrum sharing by using new technology and standards, in place of the current static band allocation. The key enabling technology of the projects mentioned above is the cognitive radio (CR), first presented. [7]. Cognitive radio is a paradigm for wireless communications in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently without interfering with the licensed users. This alteration of parameters is based on active monitoring of several factors in the external and internal radio environment, such as radio frequency spectrum, user behavior and network states. From learning the wireless environment, the cognitive radio terminal will tune to the under-utilized spectrum and make its own transmission without notice to the primary users (PUs).We first jointly consider the resource allocations in both the primary and the secondary networks, and study the optimum transmission power and rate allocations for supporting best effort traffic in the CRN.

2. SCHEDULING IN COGNITIVE RADIO NETWORKS

Classy scheduling schemes are desirable to allocate resource competently and fairly among the users in a CRN. Compared to the scheduling in traditional wireless networks, scheduling in a CRN is more complex due to the opportunistic nature of the networks [11] [12] [13]. Our work is focused on applying graph theory to spectrum allocation and traffic scheduling problems. Optimum spectrum allocation is solved for CRNs by constructing an interference graph. In [14], the unused licensed channels are allocated opportunistically to a set of cognitive base stations so that the percentage of channel usage is maximized. The joint spectrum allocation and scheduling in cognitive radio networks is studied in [12] using the proposed novel Multi-Channel Contention Graph (MCCG) to exemplify the impact of interference.

3. OPTIMUM SCHEDULING IN COGNITIVE RADIO NETWORKS.

In a CRN with spectrum underlay, the secondary links can transmit at the same spectrum as the primary links as long as the interference that the secondary links cause to the primary links is below a pre-negotiated interference threshold. The effect of setting different interference thresholds on the transmission rate of the secondary links and how the secondary transmissions affect the transmissions of the primary links is studied

3.1. System illustration

CDMA-based cellular network is primary network, where different frequency bands are used in the uplink and the downlink. Instead of communicating with the base station (BS) directly in the primary network, some mobile stations (MSs) near one another may form an ad hoc CRN and communicate directly with one another. The secondary transmissions share the same spectrum as the uplink of the cellular network through spectrum underlay, and cause interference to the uplink transmissions in the primary network. If the primary and secondary networks are tightly coupled, the CRN can share the same control channels with the primary network. The primary BS can monitor the secondary-to-primary interference and centrally control the CRN as in [17] and [20]. This is not a problem if the primary network has relatively light traffic load, which is most likely the case when a secondary network is allowed and INT_{th} is set to be reasonably high, then the control channel in the primary network has low traffic load and can be well used for the secondary network as well. An alternative way to provide the common control channel in the CRN is that the CRN can lease several mini-slots in both the uplink and downlink in the primary network for transmitting control signals. The mini-slots in the uplink channel are used for the secondary devices to report the link and interference conditions to the controller, and the mini-slots in the downlink are used for the controller to broadcast information related to admission control and packet transmission scheduling to the secondary devices. In addition, the CRN can seek out-of-band control channel as done in [21], and the control channel can be in the license-free band.

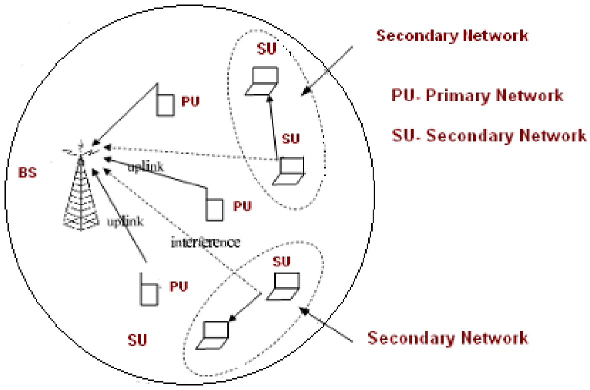

Figure.1: Design of primary and secondary networks

Since only the uplink is considered for the primary network, the transmitters are the MSs, and they share the same receiver, which is the BS. M_p and M_s, respectively, are the number of primary and secondary links. Each link has a strict signal-to-interference-plus-noise ratio (SINR) requirement at the receiver, which should be above γ^p for the primary links and γ^s for the secondary links after the signal is despreaded.

There are two interference models for measuring the interference level at the primary receivers. The first is to monitor the noise and total interference from all the secondary and the primary transmitters. This measured interference is then compared with the interference threshold, and the result is used to regulate the secondary transmissions. In this way, the interference at the primary receiver caused by the secondary transmissions is not detected separately. This model does not require a priori knowledge of the RF environment, and consequently does not need to distinguish the licensed signals from the interference and noise. The second model requires that the aggregate signal strength coming from the secondary transmitters is measured at the receiver of a primary link and compared with the interference threshold. In this case, interference caused by the secondary transmitters should be separated from that caused by primary transmitters in order to calculate the interference level. Below we formulate the power and rate allocation problem in the primary-secondary scenario based on these two interference models.

A CDMA-based system is typically interference-limited. In such a system users may transmit their signals simultaneously in the same frequency band. Each transmitter is assigned a dedicated spreading code, which can be reproduced at the intended receiver to regenerate the transmitted signal.

4. INTERFERENCE THRESHOLD

From the secondary links, a higher interference threshold allows higher transmission power and can potentially increase the transmission rate of the secondary links. On the other hand, as the secondary links increase their transmission power, they cause more interference to the primary links. As a result, transmission power of the primary links should also be increased. The mutual interference effect eventually reaches a balance, and then neither the primary nor the secondary links can increase the transmission power. Secondary-to-primary interference is maximized when at least one MS in the primary network reaches $P_{p,max.}$ Consider that homogeneous traffic is carried out by the primary links. Then for all represent the aggregate noise and interference that the ith primary link experiences from all other primary links and all secondary transmitters. With perfect power control, the actual SINR for the primary link at the BS receiver input is equal to and all the primary links have an equal received power at the BS [22].

$$P_{p,i} = \frac{P_{p,r}}{g_{p2p,ii}} \le P_{p,max} \qquad 1.1$$

That's why,

$$I_{p,i} \le \frac{G_p p_{p,max} g_{p2p,ii}}{\gamma_p^*}$$

1. 2

If, i=1, 2 ...MP $_,$ then,

$$I_{p,max} = \min_i I_{p,i} = \min_i \frac{G_p P_{p,max} g_{p2p,ii}}{\gamma_p^*}$$

1.

3

The transmission power of the second links is limited by INT_{th} to satisfy the SINR requirements of the primary links.

$$P_r\left\{I_{p,max} \le y\right\} = P_r\left\{\min_i \frac{G_p P_{p,max} g_{p2p,ii}}{\gamma_p^*} \le y\right\}$$

1. 4

$$= P_r\left\{\min_i g_{p2p,ii} \le \frac{y\gamma_p^*}{G_p P_{p,max}}\right\}$$

1. 5

$$= 1 - \prod_i P_r\left\{g_{p2p,ii} \succ \frac{y\gamma_p^*}{G_p P_{p,max}}\right\}$$

1. 6

$$= 1 - \left[1 - P_r\left\{g_{p2p,ii} \le \frac{y\gamma_p^*}{G_p P_{p,max}}\right\}\right]$$

1. 7

Ipmax can be found as,

$$E\left[I_{p,max}\right] = \int_0^\infty \left(1 - P_r\left\{I_{p,max} \le y\right\}\right) dy$$

1. 8

The distribution of $g_{p2p,ii}$ can be found as

$$\Pr\left\{g_{p2p,ii} \le \frac{y\gamma_p^*}{G_p P_{p,max}}\right\}$$

$$= \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \Pr\left\{A d_i^{-\alpha} e^{-\beta x} \le \frac{y\gamma_p^*}{G_p P_{p,max}}\right\}$$

$$= \Pr\left\{-\alpha \mathrm{In} \quad d_i - \beta x \le \mathrm{In} \frac{y\gamma_p^*}{A G_p P_{p,max}}\right\}$$

1.

The probability density function (pdf) of d is, When all

9

MSs are uniformly distributed in a circular area of radius of D, is found out from equations and it is given by

f_d (z) =

$$\Pr\left\{g_{p2p,ii} \le \frac{y\gamma_p^*}{G_p P_{p,max}}\right\}$$

$$= \int_0^D fd(z)dz \qquad \int_{-\frac{\alpha}{\beta}\mathrm{In} \quad z - \frac{1}{\beta}\mathrm{In}\frac{y\gamma_p^*}{A G_p P_{p,max}}}^{\infty} \qquad N_x(0,\sigma^2)dx$$

1.10

5. SIMULATION RESULTS

We first show the results based on the first interference model, then compare the results based on the two Interference model.

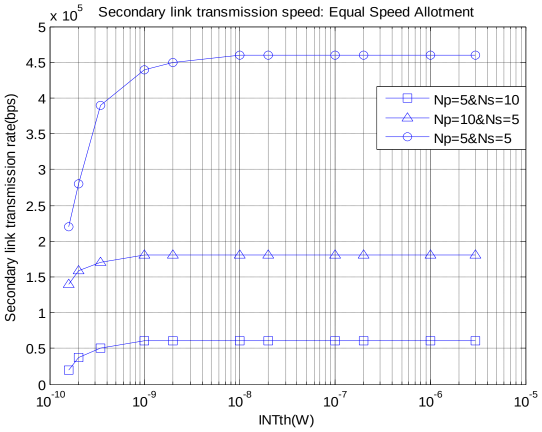

Fig 2: Secondary Link Transmission Link: ESA

Table 1. Secondary Link Transmission Link, for different values of N_p and N_s

Np=5&Ns=10	Np=10&Ns=5	Np=5&Ns=5
20000	140000	220000
38000	158000	280000
50000	170000	390000
60000	180000	440000
60000	180000	450000
60000	180000	460000
60000	180000	460000
60000	180000	460000
60000	180000	460000
60000	180000	460000

Figs. 2 and 3 demonstrate that when the interference threshold is below a certain value, the secondary link transmission rate increases with the interference threshold for both ESA and PSA.

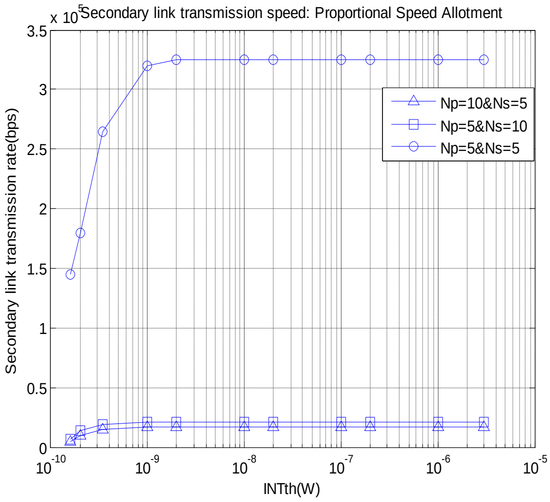

Fig 3: Secondary link transmission rate: PSA

Table 2. Secondary Link Transmission Rate: PSA

Np=10&Ns=5	Np=5&Ns=10	Np=5&Ns5
5000	6500	145000
10000	13500	180000
15000	18500	265000
17000	20500	320000
17000	20500	325000
17000	20500	325000
17000	20500	325000
17000	20500	325000
17000	20500	325000
17000	20500	325000
17000	20500	325000

Ahead of this range, further increasing the interference threshold does not affect the secondary transmission rate anymore, since the transmission of the secondary links is limited by the primary link’s SINR constraint and the mutual interference between primary and secondary networks. To sustain the SINR, the primary links will increase their power too. Once the maximized interference limit at the primary receiver is reached, the secondary users cannot further increase their transmission rate even if the interference threshold is not reached. It is also observed from both Figs. 2 and 3 that increasing the number of the primary or secondary links results in lower secondary link rate due to that more links are competing for the network resources. Comparing the two figures we can find that using PSA can achieve a lot higher transmission rate for the secondary links than using ESA, since the former can take better advantage of good channel conditions of individual links.

From fig 4. It is observed that as Dmax(m) increases, Interference to primary links reduces.

Table 3 elucidate us that INTmax reduces as ESA decreases and PSA increases.

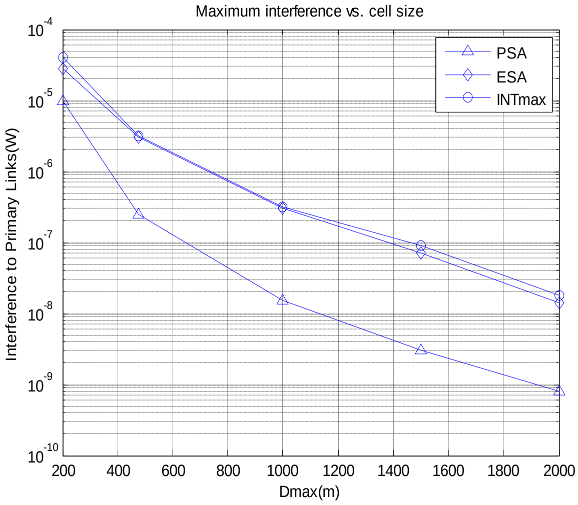

Fig 4: Highest interference vs. cell size

Table 3. INTmax for PSA and ESA related to cell size

PSA	ESA	INTmax
1.00E05	2.80E05	4.00E05
2.50E07	3.00E06	3.10E06
1.50E08	3.00E07	3.20E07
3.00E09	7.00E08	9.00E08
8.00E10	1.40E08	1.80E08

6. CONCLUSION AND FUTURE WORK

In this research work, we have simulated and designed interference model for scheduling algorithm in CDMA based CNR. The actual average interference at the primary link is also shown for ESA and PSA, respectively Results indicate that there is a limit on the interference threshold beyond which the secondary link transmission rate cannot be increased by increasing the interference threshold. Also, the increase of the secondary user transmission rate will consume additional power from the primary user, and the same amount of power increase from the primary users can support higher rate of the secondary links using proportional rate allocation, compared to using equal rate allocation among the secondary links.

From fig 5 and fig 6 we can articulate that, in disparity, PSA does not encourage the secondary links with poor SINR to transmit as high rate as the links with good SINR. When INT_{th} is small, using the second interference model achieves much higher transmission rate than using the first interference model, since in the latter case, noise and interference from the primary network can dominate the interference threshold, while in first interference model, the secondary transmissions can take advantage of all the interference allowed by INT_{th}. As INT_{th} increases, the secondary transmission power increases and eventually is limited by their mutual interference and SINR constraints, but not by INT_{th}.

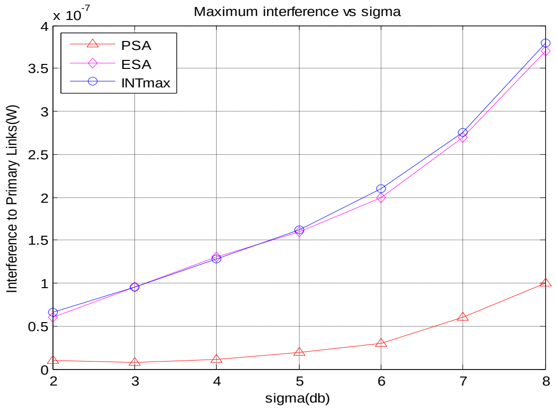

Fig 5: Maximum interference vs. Sigma

Table 4. INTmax for PSA and ESA related to Sigma

PSA	ESA	INTmax
1.00E08	6.00E08	6.60E08
8.00E09	9.50E08	9.50E08
1.10E08	1.30E07	1.28E07
1.90E08	1.60E07	1.62E07
3.00E08	2.00E07	2.10E07
6.00E08	2.70E07	2.75E07
1.00E07	3.70E07	3.80E07

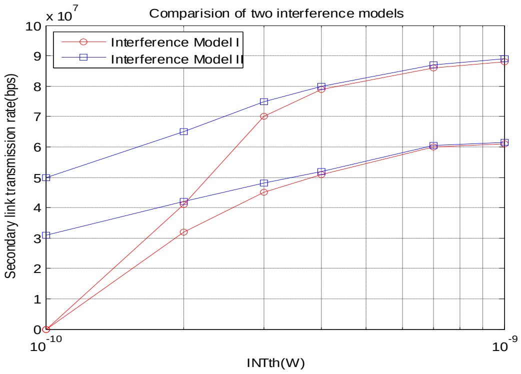

Fig 6: Comparison of two interference models

Table 5. Comparison of Interference Model 1 and 2.

INT_{th}	Interference Model I		Interference Model II	
1.00E-10	0	0	31000000	50000000
2.00E-10	32000000	41000000	42000000	65000000
3.00E-10	45000000	70000000	48000000	75000000
4.00E-10	51000000	79000000	52000000	80000000
7.00E-10	60000000	86000000	60500000	87000000
1.00E-09	61000000	88000000	61500000	89000000

At this point, the two interference models result in about the same transmission rate at the secondary network.

This work is based on specified transmission rate requirements for the traffic. Further work can be done for supporting variable rate traffic, maximizing a certain system utility function, such the throughput, subject to providing the users with a certain fairness, supporting user mobility, etc.

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8. REFERNCES

[1] Alam N. Shaikh , S. K. Bodhe, “Radio Resource Allocation Schemes in 3G and 4G Systems” in *Proceedings of* ICCRD 2011: 2011, 3rd International Conference on Computer Research and Development, 978-1-61284-840- 2/11, 2011 *IEEE*

[2] Alam N. Shaikh, S. K. Bodhe, “Performance Evaluation of Fixed Channel and Dynamic Channel Allocation Strategies in 4G” in *Proceedings of ICECECE* 2011:International Conference on Electrical, Computer, Electronics and Communication Engineering, Singapore World Academy of Science Engineering and Technology, (WASET), 81 2011, pp.817-822

[3] Alam N. Shaikh, S. K. Bodhe, “Radio Resource Management Schemes in Cellular Mobile Communication: A Comprehensive Survey “International Journal of Computational Intelligence and Information Security, Australia, June 2011 Vol.2, No.6, Pp.4-12

[4] Alam N. Shaikh, S. K. Bodhe, “Radio Resource Management in CDMA 4G Networks, Based on Mutual Frequency Assignment “International Journal of Computer Science and Network Security”, Korea, October 2011, Vol. 11 No. 10 pp. 76-83

[5] Wang, Bin, "Radio Resource Management in CDMA-Based Cognitive and Cooperative Networks" (2011).Dissertations and Thesis. McMaster University.

[6] FCC, "Spectrum Policy Task Force Report," ET Docket02-135, 2002.

[7] J. Mitola, "Cognitive radio: an integrated agent architecture for software defined radio," Ph.D. Thesis, KTH Royal Inst. Technology, Stockholm, Sweden, 2000.

[8] A. Petrin and P. G. Steffes, "Analysis and comparison of spectrum measurements performed in urban and rural areas to determine the total amount of spectrum usage, "Proceeding of the ISART, 2005.

[9] R. Berger, "Open spectrum: a path to ubiquitous Connectivity," ACM Queue, 2003.[10] C. Cordeiro and K.Challapali, "802.22: the first worldwide wireless standard based on cognitive radios," In First IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks, Baltimore, MD, USA, Nov.2005.

[10] Y. Yuan, P. Bahl, and Y. Wu, "Allocating dynamic time spectrum blocks for cognitive radio networks, "Proceedings of the 8th ACM international symposium on Mobile ad hoc networking and computing, May. 2007.

[11] Y. R. Kondareddy and P. Agrawal, "Synchronized MAC Protocol for Multi-hop Cognitive Radio Networks," IEEE ICC, vol. 25, p. 36, Beijing, China, Jun.2008.

[12] J. Tang, S. Misra, and G. Xue, "Joint spectrum allocation and scheduling for fair spectrum sharing in cognitive radio wireless networks," Computer Networks, vol. 52,p. 2148, 2008.

[13] R. Urgaonkar and M. J. Neely, "Opportunistic Scheduling with Reliability Guarantees in Cognitive Radio Networks," Proceeding of IEEE INFOCOM, Mar.2008.

[14] W. Wang and X. Liu, "List-coloring based channel allocation for open spectrum wireless networks," in Proceedings of IEEE 62nd Vehicular Technology Conference, Sept.2004.

[15] H. Zheng and C. Peng, "Collaboration and fairness in opportunistic spectrum access," in Proceedings of IEEE International Conference on Communications, vol. 5, p.3132, Hong Kong, Jun.2005.

[16] F. Kelly, A. Maulloo, and D. Tan, "Rate Control in Communication Networks: Shadow Prices, Proportional Fairness and Stability," Journal of the Operational Research Society, vol. 49, no. 6, p. 237, 1998.

[17] F. P. Kelly, "Charging and rate control for elastic traffic, "European Transactions on Telecommunications, vol. 8, p.33, 1997.

[18] J. F. Nash, "The bargaining problem," Econometrica, vol.18, p. 155, 1950.

[19] L. Zhou, "The Nash bargaining theory with non-convex problems," Econometrica, vol. 65, p. 681, 1997

[20] A. Jalali, R. Radovan, and R. Pankaj, "Data throughput of CDMAHDR a high efficiency-high data rate personal communication wireless system," IEEE Vehicular

[21] Technology Conference, vol. 3, p. 1854, Sept.2000. I. Akyildiz, W. Lee, and S. Mohanty, "A survey on spectrum management incognitive radio networks," IEEE Communications Magazine, vol. 9, no. 7, p. 40,2008.

[22] K. S. Gilhousen, I. M. Jacobs, and R. Padovani, "On the capacity of a cellular CDMA system," IEEE Transactions of Vehicle Technology, vol. 40, no. 6, p. 303, 1991.