Radio Resource Management and Design of Interference Model for Scheduling Algorithm in 4G CDMA Based Cognitive Radio Network

Alam N. Shaikh

Research Scholar, NMIMS, Deemed-to-be-University Mumbai , INDIA

S. K. Bodhe

Principal, College of Engineering Pandharpur, INDIA

Summary

In this research paper we have designed Interference Model for Scheduling Algorithm in Cognitive Radio Networks (CRNs), which is very much essential during the development of 4G. [1]. Also we shove radio resource management (RRM) in CDMA based cognitive radio networks (CRNs). 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. Organization of the transmission power is very important because the aspects of the network resource allocations, such as transmission time and rate allocations are determined by transmission power. Adequate quality of service (QoS) is the innermost aim of the RRM by interesting advantage of the available network resources. Power control is originally used to solve the near-far problems in the uplink of cellular CDMA networks when homogeneous traffic is supported. 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] [9] have discovered that 78 %(96%) of spectrum is unutilized in rustic areas. Alternatively, the demands for wireless communication services have augmented spectacularly.

Keywords:

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

1. Introduction

Radio Resource Management (RRM) plays vital role in CDMA Based Wireless Networks [3]. Naturally interference-limited system is a CDMA based system. 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 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. The system capacity and QoS to the users is enormously interrelated with the management of transmission power and mutual interference.

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 IEEE 802.22 working group on Wireless Regional Area Networks (WRAN) has been developing a new standard, focusing on constructing a consistent and point-to-multipoint WRAN that will utilize the free UHF/VHF TV bands for communication [10]. 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).

In this paper we study radio resource management (RRM) in CDMA based cognitive radio networks (CRNs). In the networks, all simultaneous transmissions share the same spectrum and interfere with one another. Therefore, managing the transmission power is very important as it determines other aspects of the network resource allocations, such as transmission time and rate allocations. The main objective of the RRM is to efficiently utilize the available network resources for providing the mobile users with satisfactory quality of service (QoS).

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. Fair transmission

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throughput is provided to the secondary links at each time slot. We then study how to support long-term best effort traffic in the CRN, and provide proportional fairness to the average throughput among links. The resource allocation problem is further extended for supporting traffic with strict QoS requirements, where admission control and packet transmission scheduling are jointly considered to provide QoS for two types of traffic, streaming traffic requiring low outage probability, and non-real time traffic with a minimum transmission rate requirement.

2. Radio Resource Management (RRM) in CDMA Based Wireless Networks

2.1. Power control

Power control is originally used to solve the near-far problems in the uplink of cellular CDMA networks when homogeneous traffic (mainly voice) is supported. A great deal of the work on power control in cellular CDMA systems has focused on how to set the transmission power so that all users in the system have acceptable SINR, or bit-energy-to-interference spectral-density ratios (E_b/I_o), which is the normalized SINR per transmitted bit.

$$E_b / I_0 = \frac{P_r / R}{(N-1)P_r / W} = \frac{W/R}{N-1} \quad 2.1$$

Where, E_b/I_o = Bit energy to interference spectral density ratios.
Processing gain is given by, W/R, capacity of the cell in the number of users can be found by solving for N,

$$N = 1 + \frac{W/R}{E_b / I_0} \approx \frac{W/R}{E_b / I_0} \triangleq N_w \quad 2.2$$

Multiple cells transmissions from neighboring cells furthermore cause interference to one another. When all the traffic is homogeneous, the interference experienced from other cells is a fixed ratio f times the interference experienced from the same cell, where f ≈ 0. In that case the per-cell capacity of a multi-cell system is given by

$$N_w = \frac{1}{1+f} \frac{W/R}{E_b / I_0} \quad 2.3$$

A new universal expression about the transmission power is given by

$$\frac{W}{R_i} \frac{P_{u,i} g_{u,i}}{\sum_{j \neq i} P_{u,j} g_{u,j} + \eta} \geq \gamma_{i.}^{*} \quad 2.4$$

In Vector form, we can rewrite the above relationship as

$$WP^T \geq \eta 1^T \quad 2.5$$

Where, $W = [W_{ij}]$ is an N × N matrix and defined as:

$$W_{ij} = \begin{cases} \frac{W g_{u,i}}{R_i \gamma_i^{*}}, & \text{When} \quad i = j \\ -g_{u,i}, & \text{When} \quad i \neq j \end{cases} \quad 2.6$$

The downlink transmission power should satisfy the following relationship,

$$\frac{W}{R_i} \frac{P_{d,i} g_{d,i}}{\sum_{j \neq i} P_{d,i} g_{d,i} + \eta_i} \geq \gamma_i^{*} \quad 2.7$$

Controlling the transmission power, the SINR of every connection can be confined, the interference to other users can be reduced, and the system capacity can be maintained.

2.2. Scheduling in cognitive radio networks

Sophisticated 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]. Early works focus on applying graph theory to spectrum allocation and traffic scheduling problems. Optimum spectrum allocation is solved for CRNs by constructing an interference graph. However, due to high computational complexity, it only applies for an ad-hoc CRN with a limited number of fixed secondary users. 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 authors then formulated this problem as a graph-coloring problem and proposed several greedy heuristics for channel allocation. A similar problem to [14] is considered in [15], where a reward function is introduced that is proportional to the coverage areas of the base stations which help the collaboration among secondary users. Again, the problem was studied based on a graph-coloring formulation. Both the works in [14] and [15] are based on the binary interference model, which does not capture the aggregate interference effects when multiple transmissions simultaneously happen on one channel. The joint spectrum allocation and scheduling in cognitive radio networks is studied in [12] using the proposed novel Multi-Channel Contention Graph (MCCG) to characterize the impact of interference. Based on the MCCG, an optimal algorithm is presented to compute the maximum throughput solutions.

3. Slot-by-slot 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 depiction

Here primary network is a CDMA-based cellular 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. For groundwork study, we consider only single hop transmissions in the CRN. As the BS is the receiver for all the uplink transmissions in the primary network, a controller for the CRN is co-located with the primary BS for measuring the interference level at the BS caused by the secondary transmissions. The controller can be a device independent of the primary BS. Alternatively, the primary and secondary networks can be tightly coupled in sometimes, and the primary BS can provide some information to assist the secondary network operation. In this case, the primary BS can also work as the controller for the secondary network. Several ways can be used for the controller and the CR nodes to exchange information. 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 INTth 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.

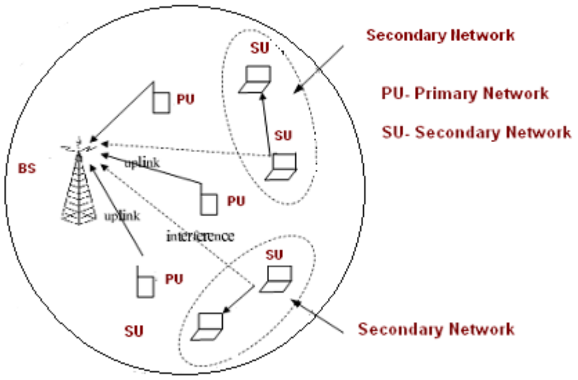

FIGURE.1 : DESIGN OF PRIMARY AND SECONDARY NETWORKS

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. Mp and Ms, 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 γp for the primary links and γs 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.

B. Optimum Rate and Power Allocation

We first consider the SINR requirement of each primary and secondary link. For a primary link, its required SINR can be satisfied if,

$$\frac{G_{p.i} P_{p.i} g_{p2p,ii}}{\sum_{j \neq i} P_{p,j} g_{p2p,ji} + \sum_{J=i}^{Ns} P_{s,j} g_{s2p,ji} + \eta} \geq \gamma_p^* \qquad 3.1$$

Where is the processing gain of the ith primary link. In the denominator on the left-hand side of (2.1), the first term is the interference from all other primary links, the second term is the interference from all the secondary links, and η is the background additive white Gaussian noise (AWGN) power.
The SINR of the ith secondary link can be satisfied if

$$\frac{W P_{s.i} g_{s2s,ii}}{R_{s,i}\left(\sum_{j \neq i} P_{s,j} g_{s2s,ji} + \sum_{J=i}^{Np} P_{p,j} g_{p2s,ji} + \eta \right)} \geq \gamma_s^* \qquad 3.2$$

The transmission power of the secondary links is also limited by the interference threshold.

$$\sum_{j \neq i} P_{p,j} g_{p2p,ji} + \sum_{J=i}^{Ns} P_{s,j} g_{s2p,ji} + \eta \leq I_{th} \qquad 3.3$$

for the first interference model,

$$\sum_{J=i}^{Ns} P_{s,j} g_{s2p,ji} \leq I_{th} \qquad 3.4$$

It is for second interference model.

Based on the above conditions we formulate the following optimization problem, which maximizes a function (normally convex) of the secondary link transmission rates, subject to the SINR requirements of the primary and secondary links and the given interference threshold, where Rs = (Rs,1, Rs,2, . . ., Rs,Ns). In the optimization problem, the constraint is based on the first interference model. If the second interference model is used, the constraint (2.8) should be changed to (2.4).

$$\text{Max } f(R_s) \qquad 3.5$$

$$\text{s.t.} \frac{W P_{s.i} g_{s2s,ii}}{R_{s,i}\left(\sum_{j \neq i} P_{s,j} g_{s2s,ji} + \sum_{J=i}^{Np} P_{p,j} g_{p2s,ji} + \eta \right)} \geq \gamma_s^*$$

$$i = 1, 2, \ldots.., M_p \qquad 3.6$$

$$\frac{G_{p,i} P_{p.i} g_{p2p,ii}}{\sum_{j \neq i} P_{p,j} g_{p2p,ji} + \sum_{J=i}^{Ns} P_{s,j} g_{s2p,ji} + \eta} \geq \gamma_p^*, i = 1, 2, \ldots.., M_p \qquad 3.7$$

$$\sum_{j \neq i} P_{p,j} g_{p2p,ji} + \sum_{J=i}^{Ns} P_{s,j} g_{s2p,ji} + \eta \leq I_{th,} \; i = 1, 2, \ldots.., M_p$$

$$\sum_{j \neq i} P_{p,j} g_{p2p,ji} + \sum_{J=i}^{Ns} P_{s,j} g_{s2p,ji} + \eta \leq I_{th,} \qquad i = 1, 2, \ldots.., M_p$$

$$\sum_{j \neq i} P_{p,j} g_{p2p,ji} + \sum_{J=i}^{Ns} P_{s,j} g_{s2p,ji} + \eta \leq I_{th,} \quad i = 1, 2.M_p$$

$$\sum_{j \neq i} P_{p,j} g_{p2p,ji} + \sum_{J=i}^{Ns} P_{s,j} g_{s2p,ji} + \eta \leq I$$

$$\sum_{j \neq i} P_{p,j} g_{p2p,ji} + \sum_{J=i}^{Ns} P_{s,j} g_{s2p,ji} + \eta \leq I_{th,} \; i = 1, 2, \ldots.., M_p \qquad 3.8$$

$$0 \leq P_{p,i} \leq P_{p,max,} \qquad i = 1, 2, \ldots.., M_p \qquad 3.9$$

$$0 \le P_{s,i} \le P_{s,max}, \qquad i = 1,2,.....,M_s \qquad 3.10$$

We consider two objective functions based on different rate allocation criteria. First, a simple equal speed allocation (ESA) is considered. That is, all secondary links transmit at the same rate. The ESA formulation provides perfect rate fairness among all the secondary links. However, links with poor SINR conditions transmit higher power to achieve the same rate as other links. Therefore, the link with the worst SINR condition limits the transmission rate of all links in the secondary network. The second rate allocation criterion is based on the proportional. The second rate allocation criterion is based on the proportional fairness (PF) for the rate allocations.The concept of PF is a good scheduling objective to balance the fairness among users and the resource utilization efficiency [16] [17].

4. Interference Threshold

A higher interference threshold allows higher transmission power from the secondary links 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 Pp,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]

$$P_{p,i} = \frac{P_{p,r}}{g_{p2p,ii}} \le P_{p,max} \qquad 3.11$$

That's why,

$$I_{p,i} \le \frac{G_p p_{p,max} g_{p2p,ii}}{\gamma_p^*} \qquad 3.12$$

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

$$I_{p,max} = \min_i I_{p,i} = \min_i \frac{G_p P_{p,max} g_{p2p,ii}}{\gamma_p^*} \qquad 3.13$$

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

$$P_r\left\{I_{p,max} \le y\right\} = P_r\left\{\min_i \frac{G_p P_{p,max} g_{p2p,ii}}{\gamma_p^*} \le y\right\} \qquad 3.14$$

$$= P_r\left\{\min_i g_{p2p,ii} \le \frac{y\gamma_p^*}{G_p P_{p,max}}\right\} \qquad 3.15$$

$$= 1 - \prod_i P_r\left\{g_{p2p,ii} \succ \frac{y\gamma_p^*}{G_p P_{p,max}}\right\} \qquad 3.16$$

$$= 1 - \left[1 - P_r\left\{g_{p2p,ii} \le \frac{y\gamma_p^*}{G_p P_{p,max}}\right\}\right] \qquad 3.17$$

Ip,max can be found as

$$E\left[I_{p,max}\right] = \int_0^\infty \left(1 - P_r\left\{I_{p,max} \le y\right\}\right) dy \qquad 3.18$$

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

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

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

$$= Pr\left\{-\alpha In \quad d_i - \beta x \le In \frac{y\gamma_p^*}{AG_p P_{p,max}}\right\} \qquad 3.19$$

When all MSs are uniformly distributed in a circular area of radius of D, the probability density function (pdf) of d is f_d (z) =

$$\Pr\left\{ g_{p2p,ii} \le \frac{y\gamma_p^*}{G_p P_{p,max}} \right\} = \int_0^D fd(z)dz \int_{-\frac{\alpha}{\beta}\ln z - \frac{1}{\beta}\ln\frac{y\gamma_p^*}{AG_pP_{p,max}}}^{\infty} N_x(0,\sigma^2)dx \qquad 3.20$$

5. Simulation Results

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

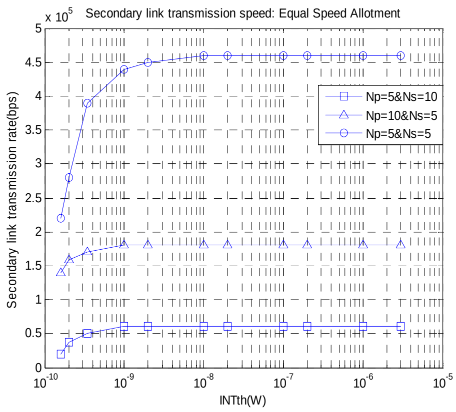

FIGURE 2: SECONDARY LINK TRANSMISSION RATE: ESA

TABLE I. SECONDARY LINK TRANSMISSION RATE : ESA ,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 show 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.

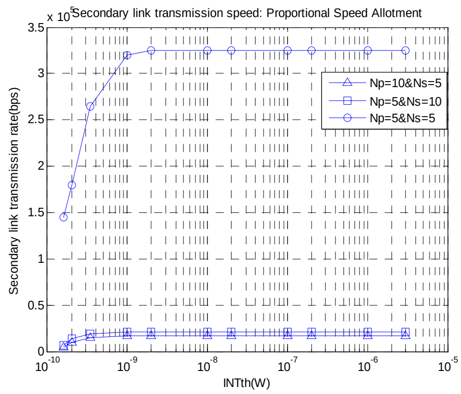

FIGURE 3: SECONDARY LINK TRANSMISSION RATE: PSA

TABLE II. 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.

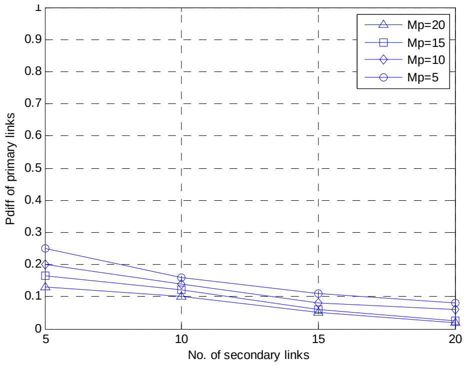

FIGURE 4: POWER DIFFERENCE OF PRIMARY LINKS: ESA

TABLE III. POEWER DIFFERENCE OF PRIMARY LINLKS: ESA

MP=20	MP=15	MP=10	MP=5
0.13	0.165	0.2	0.25
0.1	0.12	0.14	0.16
0.05	0.06	0.08	0.11
0.02	0.025	0.06	0.08

Compared to the case without the secondary links, transmission power of the primary links is increased due to extra interference from the secondary links. We define Pdiff as the difference of the average transmission power of the primary links with and without the secondary transmissions.

Fig. 4 shows that with the increase of the number of secondary links, the average primary transmission power of the primary links decreases. This is explained by the dramatic decrease of the secondary link transmission rate as the number of secondary links increases. Because of the equal rate allocation, the transmission rate of the secondary links is limited by the link with the worst link condition.

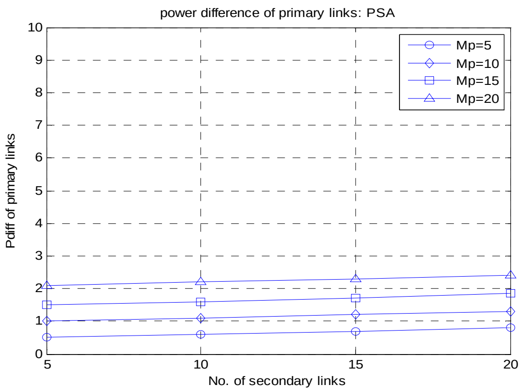

FIGURE 5: POWER DIFFERENCE OF PRIMARY LINKS:PSA

TABLE IV. POWER DIFFERENCE FOR DIFF. VALUES OF MP

MP=20	MP=15	MP=10	MP=5
0.13	0.165	0.2	0.25
0.1	0.12	0.14	0.16
0.05	0.06	0.08	0.11
0.02	0.025	0.06	0.08

Figs. 5 show that Pdiff of the primary links decrease with the number of secondary links for PSA. With the same amount of Pdiff , the CRN based on PSA can achieve much higher transmission rate than that based on ESA.

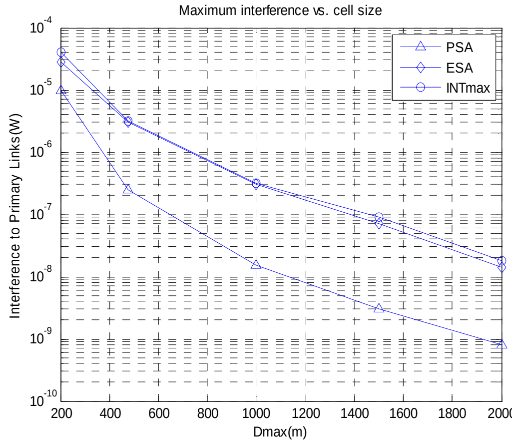

FIGURE 6: HIGHEST INTERFERENCE VS. CELL SIZE

TABLE V. 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

In this research work, we have simulated and designed interference model for scheduling algorithm in CDMA based CNR. Figs. 6-8 show Ip,max versus different system parameters. The actual average interference at the primary link is also shown for ESA and PSA, respectively

Our 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.

In contrast, PSA does not encourage the secondary links with poor SINR to transmit as high rate as the links with good SINR, and therefore the interference level at the primary links is limited by the maximum transmission power of both the primary and secondary transmitters. Transmission rate of the secondary links is shown in Fig.11 .When INTth 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 INTth. As INTth increases, the secondary transmission power increases and eventually is limited by their mutual interference and SINR constraints, but not by INTth. At this point, the two interference models result in about the same transmission rate at the secondary network.

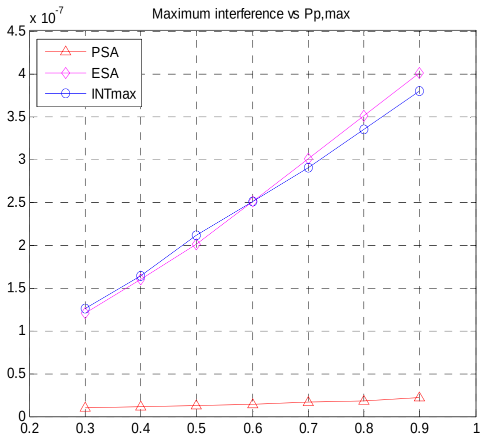

FIGURE 7: MAXIMUM INTERFERENCE vs. $P_{p,max}$

TABLE VI. INTmax FOR PSA AND ESA RELATED TO $P_{p,max}$

ESA	PSA	INTmax
1.00E08	1.20E07	1.26E07
1.10E08	1.60E07	1.64E07
1.20E08	2.00E07	2.11E07
1.40E08	2.50E07	2.50E07
1.60E08	3.00E07	2.90E07
1.80E08	3.50E07	3.3507
2.20E08	4.00E07	3.80E07

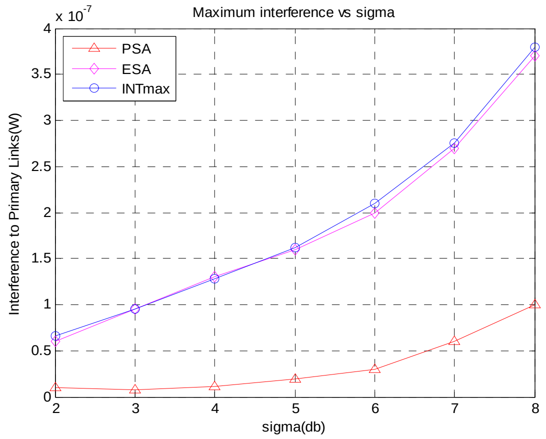

Figure 8: Maximum interference vs. Sigma

TABLE VII. INTmax FOR PSA AND ESA RELATED CTO 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

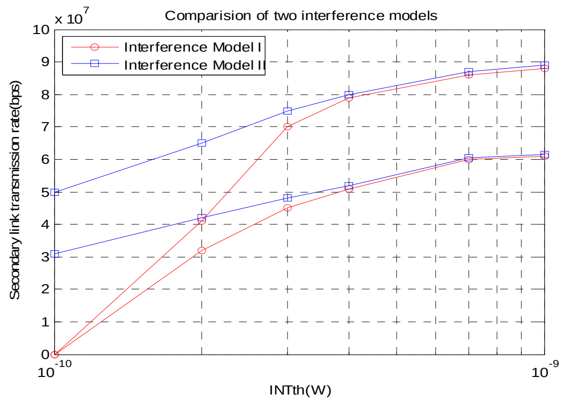

FIGURE 9: COMPARISON OF TWO INTERFERENCE MODELS

TABLE VIII. COMPARISION 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

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Alam N. Shaikh received B.E. (Electronics) and M.E. (Electronics) in 1994 and 2007 respectively from Shivaji University Kolhapur; Currently he is pursuing Ph. D. in Electronics and Telecommunications at NMIMS University, Vile Parle, and Mumbai. He has been working as H.O.D., and A.P., Dept. of EXTC, DRIEMS, Mumbai. He has Guided 9 Post Graduate students .His research interests are Wireless Networks, Mobile Communication. He has published over 20 papers in national/international journals/Conferences. He is life member of ISTE.

Shrikant Bodhe was born in September 19, 1959. He completed his Bachelor's degree in Electronics and Telecommunication in 1983 from Pune University. He completed his Masters Degree in Electronics Engineering from Shivaji University, Kolhapur, in 1989. He received his Ph.D., in Mobile Communication from Shivaji University, Kolhapur, in 1999. He is working as a Principal; at College of Engineering Pandharpur, INDIA He has many national and International publications on his name. His research interests include Mobile Communication, Wireless ad hoc networking Wireless Sensor Networks. He has Guided 40 post Graduate students. Under his Supervision 8 students have completed their Ph.D. work in the field of mobile communication. He is a member of IEEE. He has published over 82 papers in national/international journals/Conferences