A Performance Analysis of Inter-Cell Subcarrier Collision Due To Random Access in OFDM-Based Cognitive Radio Network

Miss. Asha. R
4th sem,M.Tech DCE Branch
CMRIT College, Bangalore ,INDIA

Mrs. Sujatha. S
Assoc. Prof .TCE Branch
CMRIT College, Bangalore ,INDIA

***Abstract*— In cognitive radio (CR) systems, one of the main implementation issues is spectrum sensing because of the uncertainties in propagation channel, hidden primary user (PU) problem, sensing duration and security issues. Here an orthogonal frequency-division multiplexing (OFDM) - based CR spectrum sharing system is considered, that assumes random access of primary network subcarriers by secondary users (SUs). In the absence of information about the PU's activity, the SUs randomly access (utilize) the subcarriers of the primary network and collide with the PU's subcarriers with a certain probability. In addition, inter-cell collisions among the subcarriers of SUs (belonging to different cells) can occur due to the inherent nature of random access scheme. The expression for the PMF & number of subcarrier collisions considering both fixed & random. The performance of the random scheme in terms of average capacity & capacity loss caused by the subcarrier collisions is investigated by assuming an interference power constraint at Pus to protect their operation. Each SUs attains to target signal to interference and noise ratio while ensuring interference leakage to PU is below a certain threshold. SU to implement the transmit power so its assumed that perfect information about interference channel power gain.**

Index Terms— **OFDM-based cognitive radio, random access, Inter-cell subcarrier collision, interference spreading, spectrum sharing , average capacity.**

INTRODUCTION

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications. Spectrum measurements around the globe have revealed the fact that the available spectrum is under-utilized. One of the most remarkable solutions to cope with the under-utilization of spectrum is the concept of cognitive radio (CR). CRs assume that the radio frequency (RF) spectrum can be utilized by secondary users (SUs) in addition to the legacy users also termed primary users (PUs) by complying with some predefined requirements imposed by PUs on SUs. Two of the most popular SU spectrum utilization methods are spectrum sharing and opportunistic access methods. In the spectrum sharing method, a SU can concurrently use the same spectrum with a PU by regulating (adapting) its peak or average transmit power below a PU predefined interference temperature (IT) (power) constraint, so that the quality of service (QoS) requirement of PU is maintained. In the opportunistic access method, a SU can only access the spectrum when it is not occupied by PU. Combinations of the aforementioned methods are called hybrid CR networks.

One of the most challenging issues in the implementation of CR networks is the acquisition of information about the spectrum occupancy of PU(s) [10], [11]. Deploying an efficient spectrum sensing mechanism is difficult because of the uncertainties present in the propagation channels at device and network-level, the hidden PU problem induced by severe fading conditions and the limited sensing duration. In case of a single secondary user (SU) in the secondary network, due to the lack of information of PUs' activities, the SU randomly allocates the subcarriers of the primary network and collide with the PUs' subcarriers with a certain probability. To maintain the quality of service (QoS) requirement of PUs, the interference that SU causes onto PUs is controlled by adjusting SU's transmit power below a predefined threshold, referred to as interference temperature. In this paper, the average capacity of SU with subcarrier collisions is employed as performance measure to investigate the proposed random allocation scheme for both general and Rayleigh channel fading models.

In the CR system, both SUs and the primary user (PU) share the same base station (BS). In contrast to existing SU scheduling schemes, the SU which causes the minimum interference to the PU is selected for transmission. Besides, the transmit power of the selected SU should also satisfy the outage probability requirement of the PU. An interesting observation is that both the mean capacity and the upper bound on the average BER of the scheduled SU are independent of the number of SUs and the transmit power of the PU. In this paper, two different SU transmitter and receiver pairs belonging to different cells are considered, and the performances in terms of capacity and rate loss due to collisions (interference) between SUs in addition to that of PU are studied. The average capacity expressions of target SU's (SU-1) at the *i*th subcarrier are derived for no interference case, and when there is interference from only SU-2, only PU, and both SU-2 and PU. The number of subcarriers required by PU or SUs can also vary based on either PU or SUs rate requirements .The statistical analysis of the number of subcarrier collisions between the users is also conducted. The probability mass functions (PMFs) and the average number of subcarrier collisions are derived when there are *fixed* and *random* numbers of subcarriers required by users. Finally, upper bounds for instantaneous and average maximum capacity (rate) loss of SU-1 due to collisions are derived.

The main advantage of random subcarrier access (utilization or allocation) is to uniformly distribute the SUs interference among the PUs subcarriers, a phenomenon which can be termed as *interference spreading*. Hence, the probability of accessing all subcarriers.

SYSTEM AND CHANNEL MODEL

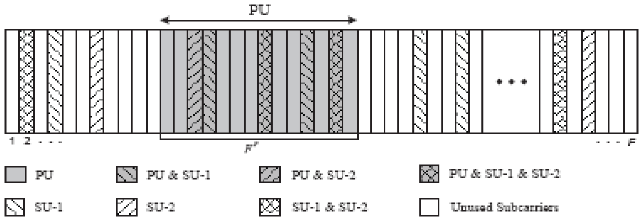

Fig 1: OFDM-based CR system for SUs in different secondary networks (cells) with subcarrier collisions with each other and PU due to the random access method.

The orthogonal frequency-division multiplexing (OFDM)- based CR system is illustrated in Figure 1, where a PU and SUs are assumed to be present in the primary and secondary networks, respectively, where each SU transmitter and receiver pair belongs to separate cells1. The total number of available subcarriers in the primary network is denoted by *F*, and the number of PU's subcarriers is denoted by FP . The number of subcarriers utilized by SU-1 and SU-2 are represented by $FS1$ and $FS2$, respectively. SUs randomly access the available subcarriers set, *F*, in the primary network without having access to the PU's channel occupancy information. Subcarrier collisions occur when SUs randomly employ subcarriers, which are in use by PU and/or other SU, and the probabilistic model for the number of subcarrier collisions follows a hypergeometric distribution. Due to the random access (allocation) of subcarriers by SUs in different secondary cells, collisions occur with a certain probability between the subcarriers of SUs and PU. In addition, intercell collisions between the subcarriers of SUs might occur in addition to those that are utilized by PU. This set-up could be considered as the worst case scenario, where the collisions among the SUs subcarriers severely affect the performance due to the overall caused interference. One can observe from Figure 1 that the occurrence of collisions can be classified into different groups such as collisions between PU and SU-1, PU and SU-2, SU-1 and SU-2, and the worst case situation that assumes collisions among PU, SU-1 and SU2.

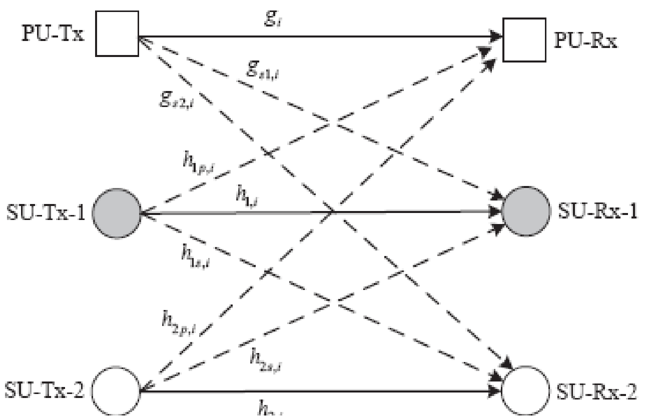

Fig 2: Channel model for the subcarrier, i ∈ {1, . . . ,F}, with SUs & PU-transmitter and receiver pairs, the performance of shaded pairs (SU-1) is of interest.

The channel model at the *i*th subcarrier (*i* ∈ {1, . . ., *F*}) is shown. The *channel power gains* from PU-Tx to PU-Rx, SU-Rx-1, and SU-Rx-2 are denoted by *gi*, *gs*1*,i* and*gs*2*,i*, respectively. Similarly, *h*1*,i*, *h*1*p,i* and *h*1*s,i* represent the channel power gains from SU-Tx-1 to SU-Rx-1, PU-Rx, and SU-Rx-2, respectively. In addition, *h*2*,i*, *h*2*s,i* and *h*2*p,i* denote the channel power gains for the *i*th subcarrier from SU-Tx-2 to SU-Rx-2, SU-Rx-1 and PU-Rx, respectively.

The performance analysis of shaded SU (SU-1) is of interest in this work. To preserve the QoS requirement of PU, the interference power levels caused by the SU-transmitters at the PU-Rx must not be larger than a predefined value for each subcarrier, referred to as the interference temperature (power) constraint. All the channel gains are assumed to be zero mean and unit variance independent and identically distributed (i.i.d.) flat Rayleigh fading channels. The channel *power* gains are hence exponentially distributed with unit mean [17]. In order for SUs to implement the transmit power adaptation and to have a tractable theoretical analysis, it is assumed that perfect information about the interference channels power gains, *h*1*p,I* and *h*2*p,i*, is available at SUs. For the sake of analysis simplicity, it is further assumed that the value of interference constraint is the same for all the subcarriers in the system, and the peak transmit power of each user is the same for all its subcarriers, i.e., *Pi* = *P*, *P*1*,i* = *P*1 and *P*2*,i*= *P*2, where *Pi*, *P*1*,i* and *P*2*,i* represent the transmit powers of PU-Tx, SU-Tx-1 and SUTx-2 for the *i*th subcarrier, respectively. The thermal additive white Gaussian noise (AWGN) is assumed to have circularly symmetric complex Gaussian distribution with zero mean and variance *σ*2, i.e., *CN* (0*, σ*2).

NUMERICAL ANALYSIS

The upper bound for the maximum average capacity loss is given by

$$E[\Delta C_{S1}] \leq \frac{T_{S1} q_{S1} (T_P q_P P_i + T_{S2} q_{S2} P_{2,i})}{\sigma^2 F}$$

The upper bound for the capacity loss of SU-1 in free case is given by

$$E[C_{S1}^{f}] = T_{S1} q_{S1} E[C_{f1,i}]$$

The percentage of average capacity loss is given by

$$E[\Delta C_{S1}] / E[C_{S1}^{f}] / E[C_{S1}^{f}]$$

The ratio of available subcarriers is given by

$R_a = \frac{F}{T_{S1}}$, F=40…….200 and $T_{S1} = 40$.

SIMULATION FIGURE

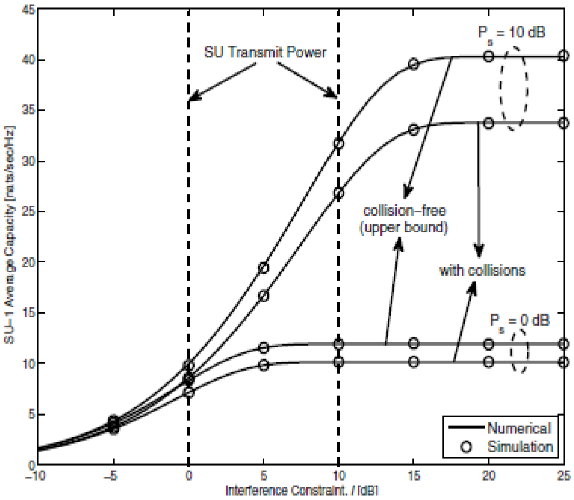

Fig. 6. SU-1 average capacity versus interference power constraint, $\mathcal{I}$, for different SU's transmit power with $T_P = T_{s1} = 40$, $T_{s2} = 30$, $F = 100$, and $P = 5$ dB.

The total average capacity of SU-1, given in (7), versus the interference constraint for different SUs' transmit powers. The simulations are performed assuming *random* subcarrier requirements for users, where *qp* = *qs*1 =*qs*2 = 0.5. where two saturation points are available due to the different values for transmit powers of SUs, *Ps* = 0dB and *Ps* = 10dB. For the sake of comparison, it is immediate to observe that when SUs have access to the perfect *spectrum sensing information*8, they can avoid subcarrier collisions, so that all the subcarriers of the SUs will be collision-free.Therefore, one can conclude that our analysis in this work can be employed as a performance comparison benchmark for the case when spectrum sensing information is available at the SUs. Notice that the difference between the capacity profiles in the collision and collision-free case depends on the selected system parameters, such as number of subcarriers, transmit powers, etc. Here in paper, the values of these parameters are arbitrarily selected. One can further observe that the collision free case can perform as an upper bound for the set-up with subcarrier collisions.

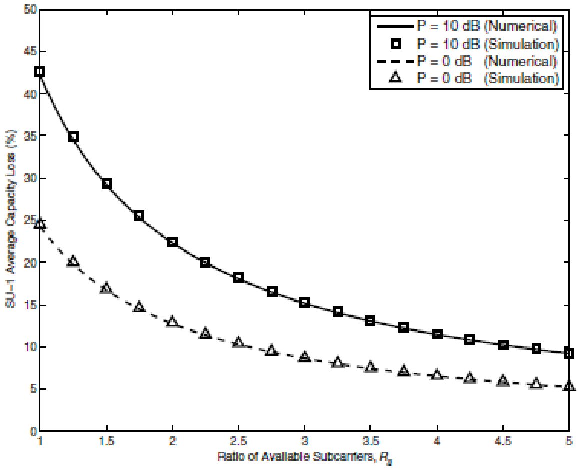

Fig. 7. SU-1 average capacity loss versus the ratio of available subcarriers to utilized subcarriers, R_a, for different PU's transmit power with $T_p = T_{s1} = 40$, $T_{s2} = 30$, $\mathcal{I} = 2$ dB, and $P_s = 20$ dB.

The average capacity loss due to subcarrier collisions is shown in figure. The percentage of average capacity loss, $E[\Delta CS1\ ]/E[CfS1]$, versus the ratio of available subcarriers to the utilized subcarriers, $Ra = F/Ts1$, $F = 40, \ldots, 200$ and $Ts1 = 40$, is shown for different values of PU's transmit power. It is immediate to observe that an increase in the number of available subcarriers in the primary network, leads to a larger number of collision-free subcarriers for SU-1.

Therefore, SU-1 average capacity loss decreases as the number of available subcarriers increases. Notice also that an increase in PU transmit power results in higher interference at SU-1, and hence higher capacity loss on the average.

REFERENCES

[1] "Spectrum policy task force," Federal Communications Commission (FCC), ET Docket No. 02-135, Tech. Rep., Nov. 2002.

[3] J. Mitola *et al.*, "Cognitive radio: an integrated agent architecture for software defined radio," Doctor Technol., Royal Inst. Technol. (KTH),Stockholm, Sweden, 2000.

[4] L. Musavian and S. A¨ıssa, "Fundamental capacity limits of cognitive radio in fading environments with imperfect channel information," *IEEE Trans. Wireless Commun.*, vol. 57, no. 11, pp. 3472–3480, Nov. 2009.

[5] L. Musavian, and S. A¨ıssa, "Capacity and power allocation for spectrum sharing communications in fading channels," *IEEE Trans. Wireless Commun.*, vol. 8, no. 1, pp. 148–156, Jan. 2009.

[6] Z. Rezki, and M.-S Alouini, "Ergodic capacity of cognitive radio under imperfect channel state information," *IEEE Trans. Veh. Technol.*, doi:10.1109/TVT.2012.2195042, 2012.

[7] Y.-U. Jang, "Performance analysis of cognitive radio networks based on sensing and secondary-to-primary interference," *IEEE Trans. Signal Process.*, vol. 59, no. 11, pp. 5663–5668, Nov. 2011.

[8] H. A. Suraweera, P. J. Smith, and M. Shafi, "Capacity limits and performance analysis of cognitive radio with imperfect channel knowledge,"*IEEE Trans. Veh. Technol.*, vol. 59, no. 4, pp. 1811–1822, May 2010.

[9] P. J. Smith, P. A. Dmochowski, H. A. Suraweera, and M. Shafi,"The effects of limited channel knowledge on cognitive radio system capacity," *IEEE Trans. Veh. Technol.*, pp. 1–7 (early access in IEEE Xplore).

[10] K. Hamdi, W. Zhang, and K. B. Letaief, "Opportunistic spectrum sharing in cognitive MIMO wireless networks," *IEEE Trans. Wireless Commun.*, vol. 8, no. 8, pp. 4098–4019, Aug. 2009.

[18] R. Zhang, "On peak versus average interference power constraints for protecting primary users in cognitive radio networks," *IEEE Trans. Wireless Commun.*, vol. 8, no. 4, pp. 2112–2120, Apr. 2009.