THINK INDIA JOURNAL

ISSN:0971-1260
Vol-22-Issue-37-December -2019

# Power distribution in Cognitive Radio Network to Increase Quality of service at Secondary user

Karri Guru Govind
*Lovely Professional University, India-144411*
*School of Electrical and Electronics Engineering*
*E-mail: karriguru.17891@lpu.co.in*

## *Abstract:*

*This paper deals with the cognitive radio network (CRN) in which cooperative spectrum sensing technique is used between cooperative nodes (CNs). Additionally, power ratio and secondary user (SU) average throughput expressions were taken into account to obtain the idea about quality of service (QoS) improvement at the SU. However, total transmitted power* ($p_t$) *and interference power are taken as constraints to find the relationship between normalized effective capacity and QoS exponent* $\theta$. *Moreover, power ratio and SU average throughput are calculated in the presence of mean channel gains. Simulation results show that in direct transmission, smaller the value of* $\theta$, *larger is the effective capacity between secondary source (SS) and secondary destination (SD).*

**Keywords–***Cognitive radio, cooperative spectrum sensing, secondary user average throughput and QoS exponent.*

## I. INTRODUCTION

The main aim of CRN is that the under-utilized licensed spectrum of the primary user (PU) should be used by SU to avoid the problem of spectrum scarcity [1]. Accessing the unused licensed spectrum is a very crucial task of spectrum sensing. While accessing the spectrum, probability of false alarm $p_f$ and probability of miss detection $p_{md}$ play an important role. In cognitive radio network (CRN), hidden terminal problem is one of the critical problems in sensing the spectrum. In wireless communication, consider three terminals A, B and C as shown in Fig. 1. When A and C terminals simultaneously send packets to B without sensing the channel, collision will occur and corrupted data will be received at terminal B. This type of problem is known as hidden terminal problem. To eliminate this problem, Cooperative spectrum sensing scheme will be used [2], [3].

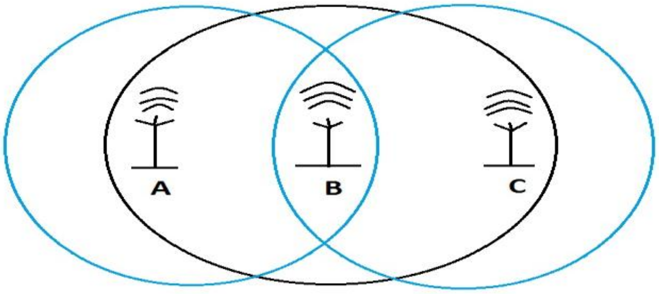

Fig. 1. Hidden terminal problem

Cooperative spectrum sensing is a scheme where group of CNs share their mutual information to achieve better performance [3]. In this paper, power allocation algorithm [4] is used to provide power to CNs in CRN. Power is allocated to CNs in such a way that SU average throughput is maximized. Additionally, power ratio expression is also calculated [4]. The authors examined on maximizing the SU average throughput, not on QoS at SU [4]. Concept related to QoS between SS and SD is explained for both direct and relay transmission cases [5].

In CRN, SU average throughput should be maximum as well as QoS must be guaranteed. This paper includes an algorithm to improve QoS at SU maximizing the SU average throughput and is developed between SS and SD for direct transmission method. This algorithm requires the concepts related to delay bound violation probability, effective bandwidth $E_B$ $\theta$) and effective capacity $E_C(\theta)$.

This paper provides these concepts and relationship between normalized effective capacity and $\theta$. Maximum average transmit power $p_{av}$, maximum average interference power $Q_{av}$ and maximum peak interference power $Q_{pk}$ were chosen as constraints in deriving the normalized effective capacity. The remaining paper will be organized as follows. II deals with system model and its algorithm. III includes the discussion with respect to simulation results and IV provides the conclusion.

## II. SYSTEM MODEL

A CRN is to be considered where cooperative spectrum sensing is used between CNs. It should have one secondary link and one primary link. Secondary link has secondary transmitter (ST) and secondary receiver (SR). Similarly, Primary link has primary transmitter (PT) and primary receiver (PR). The channel scenario between ST and CNs is non-identically distributed and independent. The system model is presented in Fig. 2. In CRN, each CN has power $p_i$ and it must be in the range of $0 \le p_i \le p_0$ where $p_0$ is the maximum individual transmission power of CN. CNs will sense the spectrum and send it's results as beacon signal to ST. If ST will detects beacon signal, it will assume that channel will be available for transmission otherwise ST assumes that channel is busy with PU. The instantaneous power gain of channel between ST and $CN_i$ is $h_i$. It will be an exponential random variable having mean $m_i$. When ST detects the channel, received SNR $\gamma$ at ST is given by [4]

$$\gamma = \sum_{i=1}^{N} p_i h_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$\eta$ is assumed as the detection threshold at ST. If the received SNR is less than $\eta$, miss detection will occur. Hence, the expression for $p_{md}$ has been derived by applying some characteristic

ISSN:0971-1260
Vol-22-Issue-37-December -2019

functions and partial fraction methods as follows [6], [7]:

$$p_{md} = pr\{\textstyle\sum_{i=1}^{N} p_i h_i \ < \ \eta\},$$
$$= 1 - \textstyle\sum_{i=1}^{N} \exp(-\frac{\eta}{m_i p_i}) \prod_{j \neq i} \frac{1}{1-(\frac{m_j p_j}{m_i p_i})} \ldots\ldots\ldots\ldots(2)$$

The equation (2) I of the form $p_{md}=1-p_d$, where $p_d$ is the probability of detection. If $p_d$ replaced with $\bar{m}=\sum_{i \epsilon N} \frac{m_i}{|N|}$ and $p_i=\rho p_t/|N|$. Then power ratio $\rho$ expression will be calculated as follows:

$$\rho = \frac{|N|\eta}{\bar{m} p_t \left( \sum_{i,j \in N} \prod_{j \neq i} \frac{1}{1-({m_j}/{m_i})} \right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The expression for secondary average throughput R was calculated from $p_{d.}$ R was given as following [4]:

$$R = \log_2(1 + \frac{h p_s}{\sigma^2}) \textstyle\sum_{i=1}^{N} \exp(-\frac{\eta}{m_i p_i}) \prod_{j \neq i} \frac{1}{1-(\frac{m_j p_j}{m_i p_i})} \ldots\ldots(4)$$

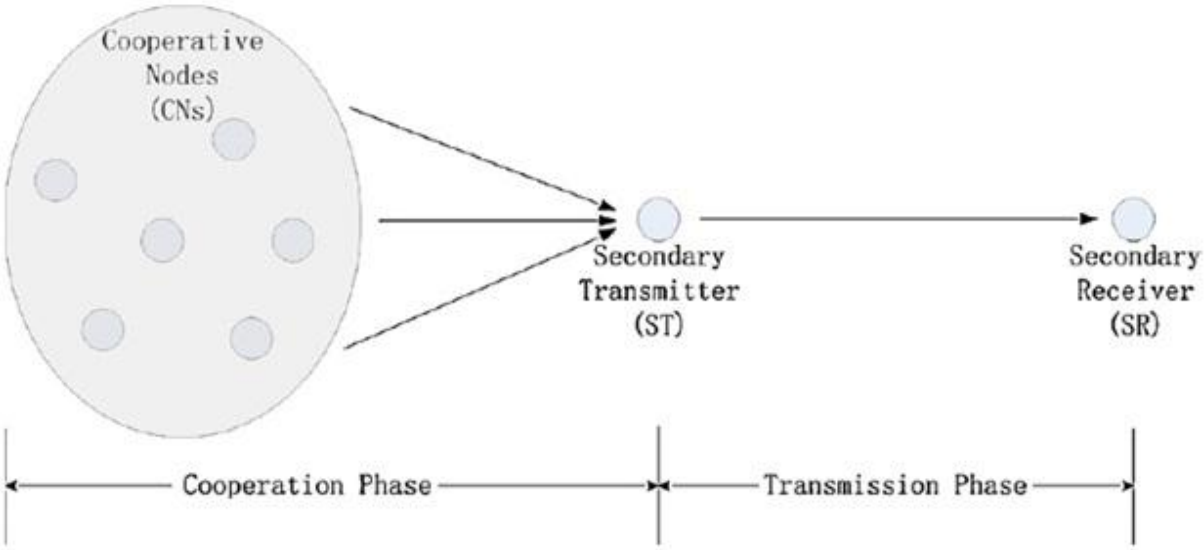

Fig. 2. Cognitive Radio Network [4]

Where $p_s$ is the transmitting power, h is the power gain of the channel between ST and SR. $p_f$ and $p_{md}$ are very important parameters in wireless communication. Pf occurs, when SU wrongly assumes that channel is ideal, but actually channel is busy with PU. Similarly $p_{md}$ occurs, when SU wrongly assumes that the channel is busy with PU, but actually the channel is ideal. The authors discussed about $\rho$ and maximizing the SU average throughput [4]. In this paper, their work has been extended to increase QoS at SU. SU average throughput was affected by $p_{md}$ only, not with $p_f$. QoS depends on interference which will be affected due to $p_f$ . So, constraints on $Q_{av}$ and $Q_{pk}$ were taken into account to increase QoS.

The relationship between normalized effective capacity and $\theta$ has been analyzed with $Q_{av}$ and $Q_{pk}$ as constraints. The proposed algorithm verifies the above relationship by assuming the condition i.e., directs transmission path exists between SS and SD. The theory concept which helped in proposing the algorithm is explained as follows. In CRN, CN has SS and SD and network gain vector (NGV) is given by:

$$G = \{g_{sd}^{pp}, g_{sd}^{ps}, g_{sd}^{ss}, g_{sd}^{sp}\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where $g_{sd}^{pp}, g_{sd}^{ps}, g_{sd}^{ss}, g_{sd}^{sp}$ represents the channel power gains from primary source (PS) to primary destination (PD) , PS to secondary destination (SD), SS to SD and SS to PD. These channel gains will not change within each frame, but change independently from frame to frame and follow nakagami-m model. Each frame duration is denoted by Tf . We split each frame into two slots. In the first slot, SS transmits its signal to SD and relays. In second slot, relays transmit to SD. In this paper, direct transmission is assumed. Hence, second slot will not be needed. SS transmits only half of its frame duration. Therefore, it uses 2Ps in first slot itself. Additionally, delay bound violation probability can be given as [5]:

$$pr\{D > D_{th}\} \leq P_{th}, \ldots\ldots\ldots\ldots\ldots(6)$$

where D, $D_{th}$ and $P_{th}$ represents delay, predefined delay bound and probability of maximum violation. The $E_B(\theta)$ and $E_C(\theta)$ can be given as [8], [9]:

$$E_B(\theta) = \frac{1}{\theta}\log\left(E\left[e^{\theta C[t]}\right]\right), \ldots\ldots\ldots(7)$$

$$E_C(\theta) = -\frac{1}{\theta}\log\left(E\left[e^{-\theta R[t]}\right]\right), \ldots\ldots\ldots(8)$$

Where C[t] and R[t] represents time uncorrelated processes and E{.} represents the expectation operator. Effective capacity is the maximum available throughput under given QoS requirement [10] and can be mathematically calculated as [5]:

$$max p_s - \frac{1}{\theta}\log\left(E\left[e^{-\theta R_{CN}}\right]\right), \ldots\ldots\ldots\ldots(9)$$

Where $R_{CN}$ is the service arrival rate of CN=$\left(T_f B/2\right)\log(1+2\gamma_1 P_s)$. (9) can be equivalent to the following equation [5]:

$$min_{p\geq 0} E[1+2\gamma_1 P_s]^{-\frac{\beta}{2}} \ldots\ldots\ldots\ldots\ldots(10)$$

Where $\beta = \frac{\theta T_f B}{\log 2}$ is normalized QoS exponent. The effective capacity (8) is calculated only if (8) satisfies the following equations.

$$P_s \leq P_{av}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11)$$

$$g_{sd}^{sp} P_s \leq Q_{av} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

$$g_{sd}^{sp} P_s \leq Q_{pk} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

Where $\gamma_1$ =effective channel power gain between SS and SD=$\frac{g_{sd}^{ss}}{g_{sd}^{ps} p_p + 1}$ , $g_{sd}^{ss}$ = channel power gain between SS and SD, $g_{sd}^{ps}$= Channel power gain between PS and SD.

The following parameters i.e., $T_f$, m, B, constant transmit power primary node $p_p$ $Q_{av}$, $p_{av}$, and $Q_{pk}$ were chosen to obtain the normalized effective capacity by using the following algorithm.

**Algorithm:**

**Input** : $T_f$, B, m, $P_p$, $P_{av}$, $Q_{av}$, $Q_{pk}$, $P_s$, r=0 and F is null matrix

**Output :** normalized_effective_capacity

```
1 : for i=0 to 1000 do
```

```
    $\gamma_1 = \frac{g_{sd}^{ss}}{g_{sd}^{ps} p_p + 1}$
    **if** $P_s \le P_{av}$ && $g_{sd}^{sp} P_s \le Q_{av}$ && $g_{sd}^{sp} P_s \le Q_{pk}$ **then**
        r ← $r + 1$
        **for** $\theta = 10^5$ $to$ $10^0$ do
            $capacity \leftarrow min_{P_s \ge 0} E[1 + 2\gamma_1 P_s]^{-\frac{\beta}{2}}$
        **end for**
        F[i]← $capacity$
    **end if**
**end for**
normalized_effective_capacity← $\frac{sum[F]}{r}$
plot figure between $\theta$ and normalized_effective_capacity.
```

## III. SIMULATION RESULTS AND DISCUSSION

This section gives the idea about input parameters and corresponding numerical results. The input parameters set to obtain the required numerical results are : Effective channel gain between ST and SR is 10dB, mean channel gain between CNs and ST are [0.1, 2, 0.3, 4, 0.5, 6, 0.7, 8, 0.9, 9], N=10, 0≤ $\eta$≤ 1, $p_{md}$=0.1, $p_0=0.3p_t/\eta$ , $T_f$=2ms, B=$10^5 Hz$ , m=2, $p_{av}$=10dB, $P_p$=20dB, $Q_{av}$=5dB and $Q_{pk}$=10dB.

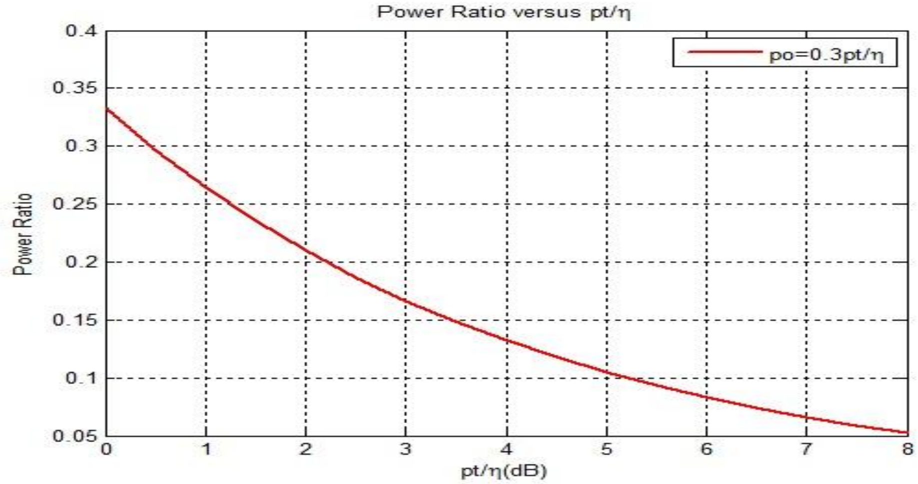

Fig. 3. Power ratio Vs $p_t/\eta$

ISSN:0971-1260
Vol-22-Issue-37-December -2019

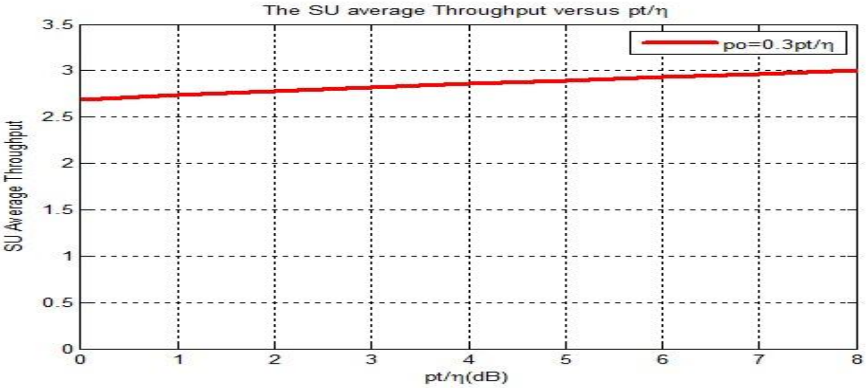

Fig. 4. SU average throughput Vs $p_t/\eta$

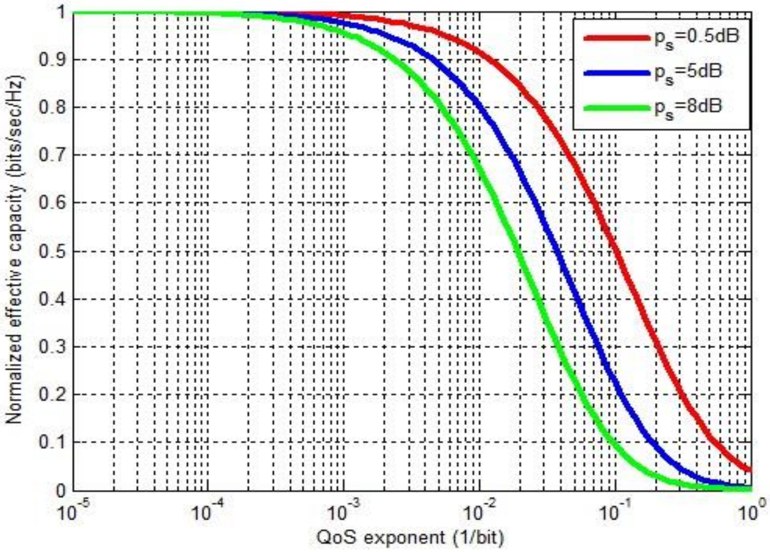

Fig. 5. Normalized effective capacity Vs QoS exponent

## IV. CONCLUSION

In this paper, QoS was analyzed between SS and SD with direct transmission (no relays) between SS and SD by considering $p_t$, $Q_{av}$ and $Q_{pk}$ as constraints. It can be concluded that when $\theta$ is less, normalized effective capacity between SS and SD should be high in direct and relay transmissions. QoS analysis with respect to relay transmission will be analyzed as future work.

## REFERENCES

**[1]**S. Haykin, “Cognitive radio: brain empowered wireless communications,” *Selected Areas in Communications, IEEE Journal on*, vol. 23, pp. 201 – 220, feb.2005.
**[2]**G. Ganesan and Y. Li, “Cooperative spectrum sensing in cognitive radio, part i: Two user

networks," *Wireless Communications, IEEE Transactions on*, vol. 6, pp. 2204 –2213, june 2007.

**[3]**G. Ganesan and L. Ye, "Cooperative spectrum sensing in cognitive radio, part ii: Multiuser networks," *Wireless Communications, IEEE Transactions on*, vol. 6, pp. 2214 –2222, june 2007.

**[4]**X. Zhang, Q. Wu, and J. Wang, "Power allocation in cognitive radio networks with cooperative spectrum sensing," *AEU - International Journal of Electronics and Communications*, vol. 66, no. 11, pp. 949– 954, 2012.

**[5]**Y. Wang, P. Ren, and F. Gao, "Power allocation for statistical qos provisioning in opportunistic multi-relay df cognitive networks," *Signal Processing Letters, IEEE*, vol. 20, pp. 43 –46, jan. 2013.

**[6]**D. Duan, L. Yang, and J. Principe, "Cooperative diversity of spectrum sensing in cognitive radio networks," in *Wireless Communications and Networking Conference, IEEE*, pp. 1 –6, april 2009.

**[7]**J. Luo, R. Blum, L. Cimini, L. Greenstein, and A. Haimovich, "Decode- and-forward cooperative diversity with power allocation in wireless networks," *Wireless Communications, IEEE Transactions on*, vol. 6, pp. 793 –799, march 2007.

**[8]**C.-S. Chang, "Stability, queue length, and delay of deterministic and stochastic queueing networks," *Automatic Control, IEEE Transactions on*, vol. 39, no. 5, pp. 913–931, 1994.

**[9]**D. Wu and R. Negi, "Effective capacity: a wireless link model for sup- port of quality of service," *Wireless Communications, IEEE Transactions on*, vol. 2, no. 4, pp. 630–643, 2003.

**[10]** X. Gong, S. Vorobyov, and C. Tellambura, "Optimal bandwidth and power allocation for sum ergodic capacity under fading channels in cognitive radio networks," *Signal Processing, IEEE Transactions on*, vol. 59, no. 4, pp. 1814–1826, 2011.