|| Volume 2 || Issue 3 || 2017 ISSN (Online) 2456-3293

OPEN ACCESS INTERNATIONAL JOURNAL OF SCIENCE & ENGINEERING

POWER ALLOCATION USING GEOMETRIC WATER FILLING AND DYNAMIC CHANNEL SENSING ALGORITHM IN COGNITIVE RADIO NETWORK

Sonal Agrawal[1], Dr. Rekha Gupta[2]
Department of Electronics Engineering, Madhav Institute of Technology and Science, Gwalior[1 2]
sonalagrawal711@gmail.com

Abstract: As spectrum scarcity is a big problem cognitive radio is an efficient solution to this problem. Orthogonal frequency division multiplexing (OFDM) is a potential technology providing many advanced functionalities in terms of power band rate control for cognitive radio networks (CRNs). Power allocation for CRNs is an important part for reduction of interference. In this paper we compare two water filling algorithm geometric water filling and dynamic channel sensing algorithm. This algorithm is optimized in a way to maximize the sum rate of secondary users by allocating power more efficiently, while constraining the 1) total transmit power, 2) individual sub channel transmit power as well as 3) individual subcarrier peak power of secondary users, for a given interference level to the primary users. Numerical results show that these algorithms provide better utilization of power resources thus maximizes the sum rate than the existing algorithms. And the power allocation is optimal. Geometric water filling is a dynamic power distribution process. The state of this process is the difference between the individual peak power sequences and the current power distribution sequence obtained by the Algorithm GWF and dynamic channel sensing algorithm provide optimal solution in terms of power is allocated intelligently and with less complexity.

***Keywords**:-geometric water filling, conventional water filling, dynamic channel sensing, OFDM system, cognitive radio network.*

I INTRODUCTION

The growing demand on wireless communication services has created the necessity to support higher and higher data rate. To meet the increased spectrum demand, FCC (Federal Communication Commission) initiated the cognitive radio technology by allowing the unlicensed user to access the licensed spectrum under certain terms of agreement between the licensed and unlicensed users. This technology provides an effective way of utilizing the scarce radio spectrum. Cognitive Radio is a well-known technology which is intelligent radio and network technology that can automatically detect available spectrum and change transmission parameters enabling more communications to run concurrently and also improve radio operating behavior. Orthogonal frequency division multiplexing better manages these issues and it is a potential technology for Cognitive radio networks too.

In OFDM, the sub-carrier frequencies are such that the sub-carriers are orthogonal to each other, meaning that interference between the sub-channels is eliminated and guard bands are not required. This greatly simplifies the design of both the transmitter and the receiver.

The organization of the rest of this paper is as follows: first is introduction section II describe the system model and OFDM based cognitive radio network and section III explain the difference between geometric water filling and dynamic channel sensing algorithm and section IV numerical and simulation result are presented and section V is future work, conclusion and references of the paper.

II SYSTEM MODEL

A typical cognitive radio system is shown in Fig. 1 where primary users (PU's) and secondary users (SU's) share the same bandwidth. In order to avoid harmful interference to each other, the SU needs to detect the opportunities when PUs is not utilizing the spectrum.

Higher detection probability without errors provides successful exploitation of opportunities for transmission. In the fig.1 different regions of cognitive radio is shown SU can detect any PU's activity within the detection region. However, those PUs that fall outside the detection region (like PU2 in Fig. 1), are undetectable by the SU. In Fig. PU2 defines a protection area whose radius is R. This also requires the interference power at the margin and at a certain value, for example η_j. Here, SUs' transmission power Ptx is tied to a power constraint, which is given by,

$$Ptx \geq \eta_j (d - R)^{\beta j}$$

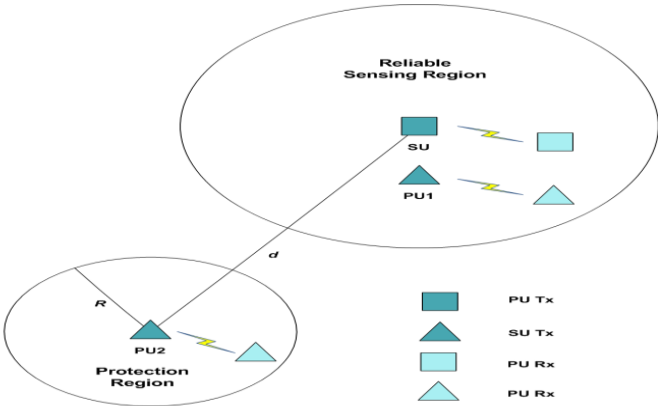

Figure 1 Different Regions of Cognitive Radio

Here, d is the distance between the SU transmitter and the nearest PU transmitter beyond the reliable sensing region. βj is the value of the path attenuation factor.

OFDM-based Cognitive Radio System

OFDM is an efficient technology for low interference and modulation because subcarriers are orthogonal to each other so we use of dm system in cognitive radio network. It is also highly flexible due to subcarrier structure to fit in cognitive radio network for efficient utilization of spectrum opportunities. In the fig.2 OFDM based CRN spectrum structure is shown. In the figure there are M sub channels licensed to M primary user systems that can be used by the secondary user (SU) based on opportunity detection. There are N subcarriers that are distributed among the M sub channels. For example, let the jth sub channel has total mj subcarriers that can be utilized by the SU when PU is absent. For successful transmission, the SU first needs to determine any PU transmitter in the desired sub channel. If found then the sum of power of all the subcarriers in that sub channel will be set to zero until the PU transmission ends.

If not, the SU can utilize this sub channel with the interference constraint described in (1). Let Gj is the interference constraint on the jth sub channel after spectrum detection, then,

$$Gj \triangleq \begin{cases} 0 & \text{PUj is detected} \\ \eta_j (\mathrm{Dj} - \mathrm{Pj})^{\beta_j} & \text{PUj is not detected} \end{cases} \quad \ldots (1)$$

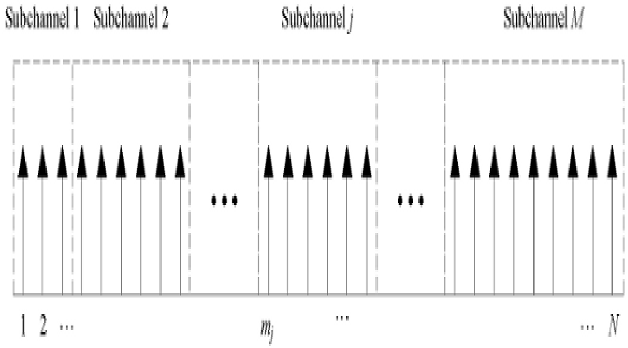

Figure 2 OFDM based CRN spectrum structure

Where, ηj is the maximum allowable interference level for PUj within the protection region whose radius is Pj, Dj is the distance between the SUs transmitter and the nearest undetectable PUj's transmitter and βj is the corresponding path attenuation factor.

For communications system it is required to maximize the mutual information between the input and the output of a channel with parallel independent sub-channels. With water-filling, more power is allocated to the channels with higher gains to maximize the sum of data rates or the capacity of all the channels.

Water Filling

In the fig. Here is graphical representation of water filling here for the problem we assume a tank whose bottom is given by the inverse of the sub channel gains and power is represented as water and bottom of tank is considered as fading which is inverse of channel gains. Here we allocate more power to higher gain channel to maximize the capacity of all the channels.

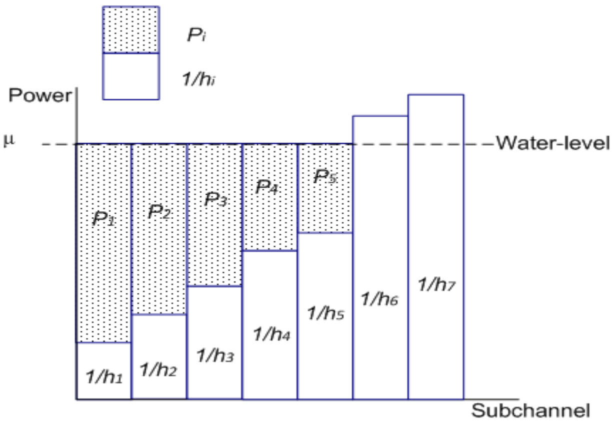

Figure 3 Graphical Representation of water filling

III GEOMETRIC WATER-FILLING METHOD

In the conventional water-filling problem is given as Problem:-given Pt > 0, as the total power or volume of the water; the allocated power and the propagation path gain for the ith channel are given as Pi and hi respectively, i = 1.........N. and N is the total number of subcarriers. Let $\{hi\}_{i=1}^{N}$ be a sorted sequence, which is positive and monotonically decreasing, find that

max$\{Pi\}_{i=1}^{N}$=$\sum_{i=1}^{N}\log(1+h_i P_i)$

subject to: 0≤ P_i for all i;

$\sum_{i=1}^{N} P_i = P_t$

To find the solution which satisfy all these constraints we usually start from the Karush-Kuhn-Tucker (KKT) conditions of the problem, as a group of the optimality conditions. The water level (μ) needs to be chosen to satisfy the power sum constraints with equality to find the optimal solution.

In paper of Peter He (2013) a geometric water-filling (GWF) approach is proposed to solve the conventional water filling problem and its weighted form. It has two advantages, they are:

1) The geometric approach can compute the exact solution to the CWF, including the weighted case, with less computation and easier analysis without determining the water level through solving the non-linear system.

2) Machinery of the proposed geometric approach can overcome the limitations of the CWF algorithm to include more stringent constraints.

Instead of trying to determine the water level μ, which is a real nonnegative number, the water level step is the target to solve.

Let us use d_i to denote the “step depth" of the ith stair which is the height of the ith step to the bottom of the tank, and is given as

$d_i = \frac{1}{h_i}$ For i=1,........N

Since the sequence hi is sorted as monotonically decreasing, the step depth of all the stairs [1,......, N] is monotonically increasing. We further define $\delta_{i,j}$ as the step depth difference of the ith and the jth stairs, expressed as,

$\delta_{i,j} = d_i - d_j = \frac{1}{h_i} - \frac{1}{h_j}$, as i $\geq j \; and \; 1 \leq i,j \geq N$

In the following, we explain how to find the water level step n^* without the knowledge of the water level μ. Let Pt (n) denote the water volume above step n or zero, whichever is greater. The value of Pt (n) can be solved by subtracting the volume of the water under step n from the total power P_t as,

$$P_t(n) = \left\{P_t - \left[\sum_{i=1}^{n-1}\left(\frac{1}{h_n} - \frac{1}{h_i}\right)\right]\right\}$$

$= \{P_t - [\sum_{i=1}^{n-1}(\delta_{i,j})]\}$,for n=1,.......,N

Due to the definition of P_t(n) being the power (water volume) above step n, it cannot be a negative number. Therefore we use $\{.\}^{+}$+ in (1.5) to assign 0 to P_t(n) if the result inside the bracket is negative. The corresponding geometric meaning is that the nth level is above water.

The above result is the shadowed area in Fig. 3 which is also an expansion of the composite form of (1.5). Then the following proposition was proposed:

The explicit solution to (1.1) is:

$$P_i = \begin{cases} P_n^* + (d_{n^*} - d_i) & 1 \leq i \leq n^* \\ 0 & n^* < i \leq N \end{cases}$$

Where the water level step n^* is given as

$n^* = max\{n | P_t(n) > 0, 1 \leq n \leq N\}$

The power level for this step is

$$P_{n^*} = \frac{1}{n^*} P_t(n^*)$$

IV DYNAMIC CHANNEL SENSING ALGORITHM

In dynamic channel sensing algorithm we obtain the value of fading. In this there are various constraints these are

1. Total sub channel power constraint
2. Individual peak power constraint and priority is given to highest sub channel power constraint which is denoted by G_j.We arrange G_j in descending order. Let Pt is the total power, fi is fading, Bi is temporary allocated power by using geometric water filling algorithm.

Firstly we allocate temporary power using Geometric water filling. Then we check what the difference between temporary power and actual power is then we start DCSI as shown in the flow chart .by checking these conditions as shown in flow chart we allocate extra power to the subcarriers where power is less than the peak power constraint and priority is also considered for power allocation. In a sub channel minimum power is allocated to the subcarriers which have highest fading and we get the optimal solution.

Example: A case of the water-filling with individual peak power constraints (WFPP) problem:

Max$\{Pi\}_{i=1}^{N}$=$\sum_{i=1}^{N}\log(1+h_i P_i)$.... (1.1)

subject to: 0≤ $P_i \leq s_i$for all i and $\sum_{i=1}^{15} p_i \leq 159$

where hi is the channel gain generated by Rayleigh distribution and is given by the array as given [0.0303 0.0333 0.04 0.0667 0.04 0.0667 0.0667 0.04 0.0286 0.02 0.025 0.025 0.0303 0.04 0.0333] The problem given is a CWFPP problem In Fig.2, the step depth is given as[33 30 25 15 25 15 15 25 35 50 40 40 33 25 30] , as the reciprocal of their respective channel gains. And peak power constraints are [8 10 22 35 6 35 28 22 5 0 3 0 7 18 4] and the power allocated using conventional water filling with peak power constraint and geometrical water filling with peak power constraint are [5.75 8.75 13.75 23.75 6 23.75 23.75 13.75 3.75 0 0 0 5.75 13.75 4]and [7 10 15 25 6 25 25 15 5 0 0 0 7 15 4] respectively and they are shown in fig. 4(a) and 4(b) respectively.

In the dcsi other constraint are also considered like total sub channel power constraint for the given example we assume Gj=[69 44 29 17] and there are 4 sub channels in this example number Of subcarrier in sub channel 1 is {1 2 3 4} in sub channel 2 is{5 6 7}in sub channel 3 is {8 9 10 11} in sub channel 4 is {12 13 14 15}

And the output of DCSI given as [8 10 22 29 6 20 20 21 5 0 3 0 3 11 4] and shown in fig.4(c)

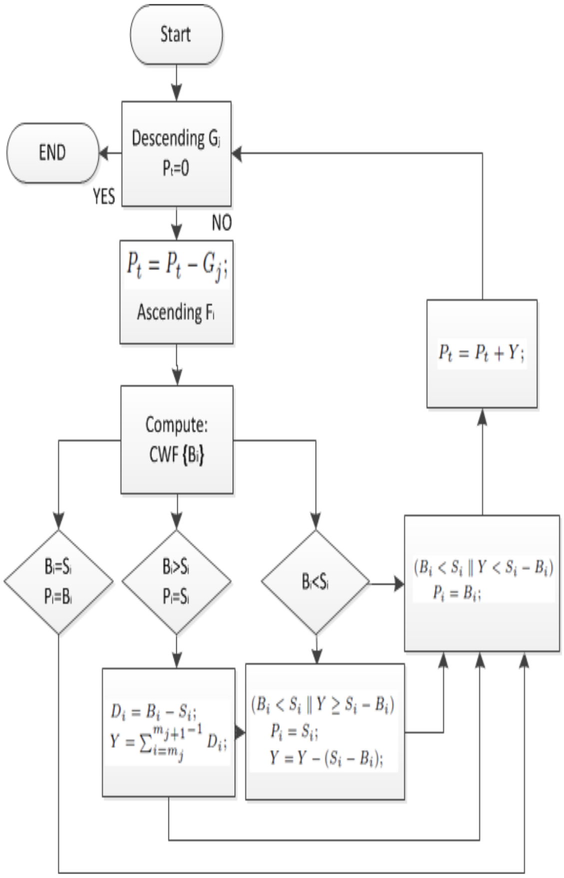

Figure 4 Case-I in terms of power allocation

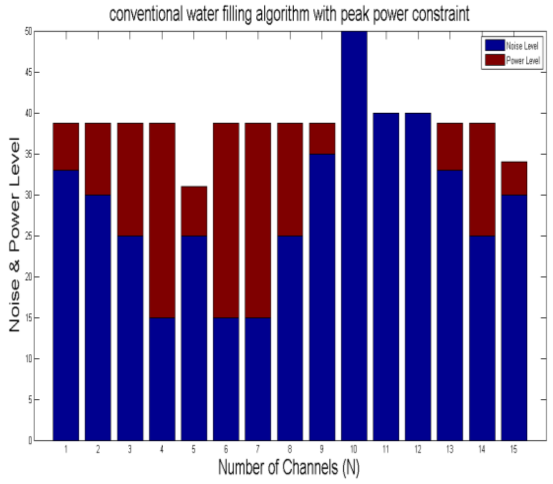

Figure 4(a) Conventional water filling algo. With peak power constraints

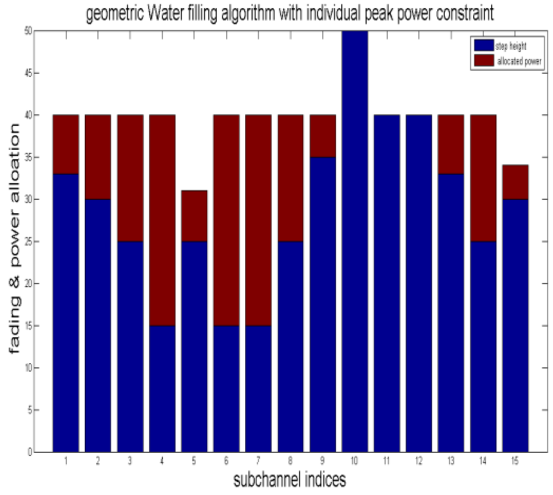

Figure 4(b) Geometric filling algoritham with individual peak power constarint

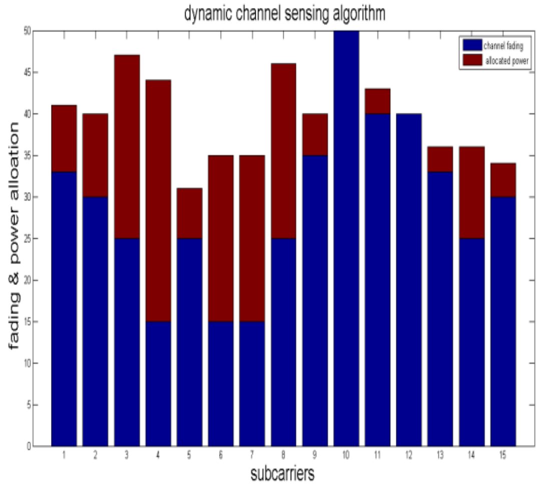

Figure 4(c) Dynamic Channel Sensing Algorithm

CASE-2 in terms of capacity

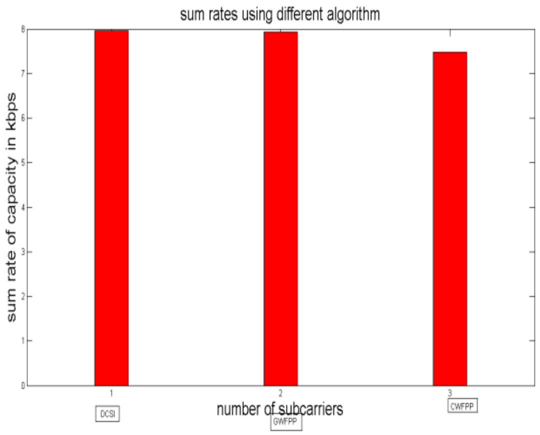

Figure 4(d) Sum Rates using different algorithm

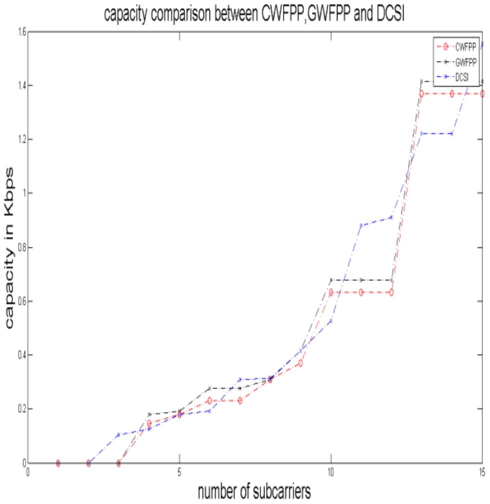

Figure 4(e) Capacity comparison between CWFPP, GWFPP and DCSI

IV CONCLUSION

From the simulation results we can conclude that optimal power allocation is done using DCSI algorithm as in the DCSI total sub channel power constraint is also considered. In the GWFPP sub channel total power constraint is not considered so power allocation obtained using this algorithm is not as much as optimal as DCSI and sum of dta rate is also increases as compared to CWFPP algorithm.

V FUTURE WORK

For radio resource allocation (RRA), one of the most typical problems is to solve power allocation using the conventional water-filling due to its nonlinear equations. As communication system develops, the structures of the system models and the corresponding Radio resource allocation problems evolve to more advanced and more complicated ones with low complexity. Conventional water-filling (CWF) and geometric water filling (GWFPP) and weighted geometric water filling with peak power constraint is not enough to approach these sort of problems. In future we can find the better technology for optimal power allocation other than geometric and Geometric water filling with some other constraint like individual peak power constraint and dynamic channel sensing algorithm with individual peak power constraint for the subcarriers and sub channel power constraint.

REFERENCES

[1] P.He, L.Zhao, S.Zhou, and Z.Niu, “Water-Filling: A Geometric Approach and its Application to Solve Generalized Radio Resource Allocation Problems," Wireless Communications, IEEE Transactions, vol. 12, no. 7, pp. 3637 { 3647, 2013.

[2] P.Wang, M.Zhao, L.Xiao, S.Zhou, and J.Wang, “Power Allocation in OFDM-Based Cognitive Radio Systems," Global Telecommunications, GLOBECOM. IEEE, pp. 40614065, 2007.

[3] D. P. Palomar and J. R. Fonollosa, “Practical algorithms for a family of water filling solutions," IEEE Transaction on Signal Processing, vol. 53, no. 2, pp. 686{695, 2005.

[4] S.Haykin, “Cognitive Radio: Brain-Empowered Wireless Communications," IEEE Journal on Selected Areas in Communication. vol. 23, no. 2, pp. 201{220, February 2005.

[5] Aniqua Tasnim Rahman Antora “power allocation in ofdm-based cognitive radio systems using iterative algorithms” 2013.

[6] Q. Zhao and B.M.Sadler, “A survey of dynamic spectrum access: signal processing, networking, and regulatory policy,” IEEE Signal Processing Magazine, vol. 55, no. 5, pp. 2294 – 2309, May 2007.

[7] K. Hamdi, W. Zhang, and K. B. Letaief, “Power control in cognitive radio systems based on spectrum sensing side information," IEEE International Conference on Communications (ICC), pp. 5161{5165, 2007.

[8] Q.Qi, A.Minturn, and Y.Yang, “An Efficient Water-Filling Algorithm for Power Allocation in OFDM-Based Cognitive Radio Systems," Systems and Informatics (ICSAI), International Conference. pp. 2069 {2073, 2012.