International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

December 2022 | Issue 53 | Volume 14 | Number 4 | Pages 195-202

OPTIMIZATION-BASED SPECTRUM SENSING IN CRN FOR EFFECTIVE UTILIZATION OF AVAILABLE CHANNEL

B.B. Kathiriya [1] D.R. Keraliya [2]

1. EC Engineering Department, Gujarat Technological University, Ahmadabad, India, bbk261981@gmail.com
2. EC Engineering Department, Government Engineering College, Rajkot, India, drkeraliya@gmail.com

Abstract- Cognitive radio networks (CRN) are subjected to the challenge of demand in available resources, limited fair resource allocation between users in the heterogeneous CRN. The availability of minimal resources affects the channel allocation between Primary Users (PUs) and Secondary Users (SUs). In heterogeneous CRNs, efficient resources are available to SUs with fair resource allocation in a multi-hop environment. This paper proposed an efficient resource allocation in multi-hop CRN through Monte-Carlo Normal Form (MCNF). The proposed MCNF is involved in the optimization of the available resources through the estimation of the objective function. With Monte-Carlo estimation, MCNF computes the optimal resource availability within the CRN. Based on the Normal Form game theory resource availability of the network is computed and allocated between the users. The performance of the proposed MCNF is computed in terms of throughput, PDR, and running time. The proposed MCNF is comparatively examined with conventional game theory and the Monte-Carlo technique. The simulation analysis of the proposed MCNF expressed that running time is reduced with increased Packet delivery rate (PDR) and throughput.

Keywords: Cognitive Radio Networks (CRNs), Secondary Users (SUs), Channel Allocation, Optimization, MCNF (Monte-Carlo Normal Form).

1. INTRODUCTION

In recent years, the drastic advancement of wireless telecommunication requires the appropriate allocation of the radio spectrum. The primary challenge associated with the wireless communication medium is the significant utilization of the available radio spectrum. In wireless radio technology, spectrum availability is limited and expensive for available resources. The drastic advancement of wireless communication is subjected to the scarcity of resources in the radio spectrum. According to a report presented by the Federal Communication Commission (FCC) [1] stated that among available resources only some portion alone utilized effectively. The other portion of the resource spectrum is either underutilization or unused.

The spectrum utilization needs to be improved and a possible solution to allocate dynamic resources utilized for cognitive radio networks [2, 3].

With 5G technology advancement, heterogeneous network demand for effective operation in the same condition. To provide a significant solution for dynamic resource scenarios, it demands the integration of cognitive radio technology in the existing radio access network [4]. Hence, in the field of wireless communication important paradigm is observed as a cognitive radio network. Based on the knowledge related to the surrounding radio environment Cognitive Radio Network (CRN) adjusts resource availability. Generally, CRN effectively utilizes available licensed spectrum effectively and opportunistically for achieving higher performance efficiency. This leads to significant improvement in the utilization of the radio spectrum in CRN. The CRN incorporates components such as cognitive radio base station, Primary User (PU), and Secondary User (SU). In the CRN network, the spectrum is sensed to detect the unused spectrum (E_1, ..., E_N) for the effective utilization of the available spectrum. To access the dynamic spectrum, the CRN is considered an effective choice, this efficiently evaluates the unused spectrum and provides spectrum opportunistically [5]. In Figure 1, the spectrum sensing mechanism in CRN is presented.

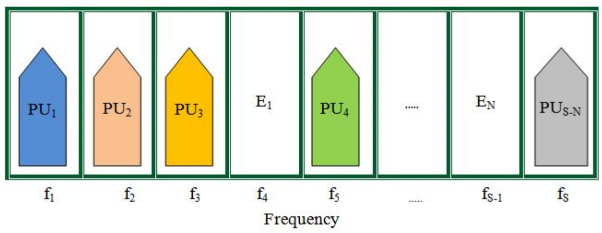

Figure 1. Spectrum Sensing for different channel

In the CRN network, the unused spectrum is opportunistically estimated for significant utilization of the available spectrum. To withstand the demand of resource scarcity, an important factor considered is device design for achieving Energy Efficiency (EE). The constructed Wireless technologies provide a considerable contribution to the spectrum environment.

The device without extended usage EE optimization impacts the device performance with improved electromagnetic radiation and resulted in an environmental factor. Usually, Cognitive Radio (CR) devices are incorporated with batteries which demand improving EE in CR devices. The unused frequency can be identified with CR devices using spectrum sensing. It is necessary to evaluate CR devices for improving accuracy and efficiency [6]. The issue related to CRN can be subjected to challenges for PU and SU sensing of the spectrum. Hence, it is necessary to evaluate spectrum allocation for both PU and SU.

2. RELATED WORKS

This section presented related works for resource allocation with both PU and SUs. In multiple SUs issues are examined based on the grade service approach for prioritizing PUs, SUs in both real and non-real-time scenarios [7]. In [8] for fully connected CRN, using pre-emption of channel unused frequency spectrum is estimated for real-time SUs. Moreover, in [9] examined Time Constant Spectrum (TCS) instead of a single target channel allotment is estimated. Also, in [10] spectrum leasing is considered as fundamental access with opportunistic spectrum allocation. In [11], for the generation of TCS, the probabilistic model is implemented with the exploitation of different SU sequences. However, the performance of fairness or resource allocation is not examined. Under the implementation of two transceivers for each SUs cost-effectiveness or energy efficiency is not examined. Similarly, [12] estimated a dynamic channel for channel backup with consideration of TCS.

To evaluate the performance of varying network CRN network conditions two metrics are considered for analysis such as the probability of link maintenance and disruption rate of connection. In [13], with the implementation of the adaptive control technique, link maintenance conditions are enhanced with backup channels. However, in another research [14] no explored calculation is performed for TCS or resource allocation issues. Further, in SU transceiver adaptively controlling mechanism is focused on multi-user CRN network SUs. This leads to an additional delay estimation mechanism for the estimation of inappropriate Voice over IP (VoIP) traffic in the network. In [15], to eliminate the disruption in handoff probabilistic estimation of CRN channels based on periods and channel conditions are reduced. Based on the information gathered from SUs about channel usage spectrum is estimated. An analysis of prior literature on the channel allocation between PUs and SUs focused on the identification of unused channels alone. The parameters associated with fairness performance are not examined clearly. To withstand those limitations, this research focused on the effective allocation of the channel between PUs and SUs in CRN. Multi-objective analysis done for question answering system [17]. Important analysis done in cognitive radio network for energy harvest [18].

3. SYSTEM MODEL

In a Conventional CRN network, the function of Certificate Authority (CA) focused on reducing communication complexity within a decentralized local Base Station (BS). The CR performance is involved in resource availability between PUs and SUs. To gain information about channel SUs should register in CA, and then SUs broadcast requests to BSs for requesting available channels required for communication. Through the verification of the legitimacy of SUs verification is performed in BSs and legally allocates the channel. The construction of the CRN network is stated as follows [16]:

- CA: This is considered a trusted authority involved in the storage capacity of the channel. In this paper, CA is involved in the initialization of the system, generation of a key, and registration of SUs.
- SU: The CRN has incorporated technology into consideration of various networks. Usually, SUs are mobile devices with limited battery energy and computing capability, and so on. However, SUs needs to register themselves in CA for achieving authentication about SUs secret parameters.
- DataBase Entity (DB): This provides information about the available channel for localization of secondary users.
- BS: In the real world, SUs access points are BSs which is similar to a real-world base station. In the developed model, BSs focused on channel pre-requesting information from the DB and allocate a channel to SUs with the appropriate authentication scheme. Every CA key received from BS is preshared and authentication is performed. Figure 2 provides the overall flow of the proposed MCNF.

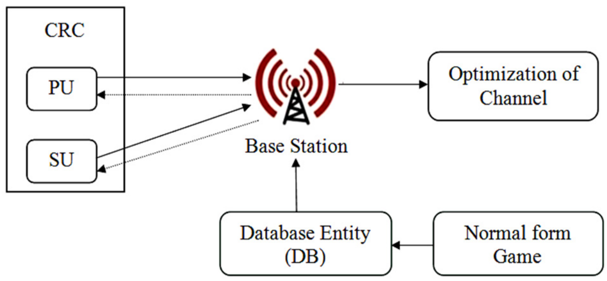

Figure 2. Overall Flow of Proposed MCNF

In the developed scheme, the function of CA's is in the decentralized form with local BSs for reducing communication complexity and workload. The information about channel availability SUs need to register themselves in CA. The BSs evaluate the performance of SUs allocated channel SUs legally. The normal form game theory is incorporated within the constructed network for improving resource allocation in the channel. In normal form theory, channels are estimated for their corresponding resource availability in terms of payoffs.

4. MCNF NORMAL FORM OPTIMIZATION ALGORITHM

To estimate the channel allocation between PUs and SUs three-game models are considered for resource allocation. The available resources are stated as $i \in N$ the unlicensed space for each channel is denoted as Si and the incoming channel is represented a Ui. Here, based on the decision-making elements game is deployed with maximizing resource utilization level. With consideration of players' situations strategy decisions are achieved. The space for strategy provides participants time and action. The layer player payoff is based on the utility level of resources to achieve a specified strategy. For the strategic decision of players income resources are optimized and action of criteria is achieved. The constructed normal form game theory is optimized for its resource utilization level based on the application of strategy. The developed MCNF model is deployed in CRN especially for Long Term Evolution (LTE) networks. The functionality of MCNF is based on consideration of participants and the strategy which is deployed over the CRN model is stated as follows:

- Participants: The participants of the game are the LTE network and Wireless Local Area Network (WLAN).

Strategy: The strategy for the deployed game is based on the consideration of the strategy adopted in LTE for achieving efficient bandwidth for the LTE coverage band. The WLAN bandwidth is allocated based on the WLAN coverage area.

- Revenue/Resources: The resource availability in the LTE bandwidth for the coverage area is provided. The coverage resource area of both LTE and WLAN is defined in Equation (1) and it is expressed as follows:

$$U = \alpha \begin{bmatrix} N^{R1} \log\left(\beta \dfrac{B_{Ap1}^{R1}}{N^{R1}}\right) + N^{R2} \log\left(\beta \dfrac{B_{Ap2}^{R2}}{N^{R2}}\right) + ... \\ ... + N^{Rm+1} \log\left(\beta \dfrac{B_{Apm+1}^{Rm+1} + B_{Ap1}^{Rm+1}}{N^{Rm+1}}\right) \end{bmatrix} \tag{1}$$

As stated, the normal form game is similar to that of the cooperative game theory model which is defined by Nash equilibrium. To estimate the Nash equilibrium for MCNF following derivation is performed. Consider non-cooperative games stated as $G = \{P, S, U\}$ with n participants/players. The players incorporated in-game is denoted as $P = \{p_1, p_2, ..., p_n\}$, where each player has their own set of policies and elements of $S^* = \left(s_1^*, s_2^*, ..., s_n^*\right)$, each player strategy is defined as s_i^* . The strategy of each payer is represented as for i players. The strategy collected by each player is denoted as $S_{-i}^* = \left(s_1^*, ..., s_{i-1}^*, s_{i+1}^*, ..., s_n^*\right)$. The resource collected strategy of the player can be stated in Equation (2):

$$\mu_i\left(s_i^*, S_{-i}^*\right) \geq \mu_i\left(s_i, S_{-i}^*\right), \forall s_i \in S, i \in [1, n] \tag{2}$$

The player strategy characteristics are summarized to achieve the optimal strategy. The best player is identified based on the Nash equilibrium concept. The Nash equilibrium evaluates the dynamic relationship between players. When a player is identified, other players make a decision but that alone does not increase resources. For optimal resource allocation, Nash equilibrium adopts second-order derivatives stated in Equation (3).

$$\frac{\partial^2 U}{\partial^2 B_{AP1}^{R2}} = -\frac{N^{R1}}{\left(B_{AP1} - \sum_{i=2}^{mn+m+1} B_{AP1}^{R1}\right)^2} - \frac{N^{R2}}{\left(B_{AP1}^{R2} + B_{AP2}^{R2}\right)} < 0 \tag{3}$$

It is observed that mixed partial derivatives are negative. Based on mixed partial derivatives Nash equilibrium is estimated using Equation (4).

$$\frac{\partial^2 U}{\partial B_{AP1}^{R2} \partial B_{AP2}^{R2}} = -\frac{N^{R2}}{\left(B_{AP1}^{R2} + B_{AP2}^{R2}\right)} < 0 \tag{4}$$

The application of second-order partial derivatives provides the utility function and mixed partial derivatives value of less than zero. It is known that the Nash equilibrium is unique for varying coverage areas and networks. By this means, resource allocation is optimized and resources are effectively optimized.

The available resources are optimized for the fair allocation of resources to both PU and SU. Normal form game theory focused on two factors such as cooperation and defect between players or channel resources. Here, the user coverage area is estimated for analyzing the network layer to the bandwidth region. The resource estimation between channels with a normal form game is calculated with consideration of various region bandwidths. For analysis, the total bandwidth of the channel is stated as, and the coverage area is defined as R_i. The total bandwidth is calculated using Equation (5).

$$B^{R_i} = \begin{cases} B_{AP_j}^{R_i} & j \in \{1\}, i \in \{1\} \\ B_{AP_1}^{R_i} + B_{AP_j}^{R_i} & i, j \in \{2, ...m+1\}, i = j \\ B_{AP_1}^{R_i} + B_{AP_j}^{R_i} + B_{AP_k}^{R_i} & i,\ k \in \{m+2, ...m \times n+1\}, \\ & j \in \{2, ...m+1\} \end{cases} \tag{5}$$

The number of users available within the network and its demand is estimated using the queuing model. This model uses a queuing window for estimation of connection distribution within a specified area, the user blocking rate is calculated using Equation (6).

$$P^{R_i} = \frac{\left(V^{R_i}\right)^{N_i} / N_i!}{\sum_{j=0}^{N_i} \left(V^{R_i}\right)^j / j!} \tag{6}$$

where, N_i represents the number of connections available within the allocated system R_i. Provides details about the number of resources utilized within coverage area R_i. The total channel is stated as N_i and the total number of users is represented as j. The channel utilization rate E_i is calculated using formula (7):

$$E_i = \frac{V^{R_i}\left(1 - P^{R_i}\right)}{N_i} \tag{7}$$

The key indicator for effective allocation of network communication is the blocking rate, this varies between users. To minimize the blocking rate of channel resources, need to be allotted statistically for the number of connections. The first resource Ri utilized within the region N^{R_i} is calculated based on the distribution model with consideration of bandwidth B^{R_i}. The average connection bandwidth is calculated using Equation (8):

$$\bar{b} = \left[\frac{B^{R_i}}{N^{R_i}} \right] \tag{8}$$

Algorithm 1 presented about game theory applied in CRN for resource allocation between PU and SU are presented.

Algorithm 1. CRN Normal Form Game Theory

```
Input: the threshold of the blocking rate, the increase of the regional user K;
Output: connection request acceptance
 for j=1:k
P_curent CalCurrentBlockingProbability( );
AdmissionConnection(  );
AreaNumberOfUserAdd( );
 end if
 time 0;
while(time<=adjustmentThreshold)
addAreaBandwith( );
getAreaConn( );
 P CalCurrentBlockingProbability( );
if(P <Ri)
admissionConnection( );
areaNumberOfUserAdd( );
break;
 end if
 time++;
end while
 if(time==adjustmentThreshold)
return admissionUser;
end if
end for
```

Based on the above-mentioned algorithm network time complexity factor and change in user is calculated. The stated algorithm adjusts the resources concerning PU and SU.

4.1. MCNF Game Theory with Optimization

Normal form game theory stated in Section 4 calculates the available resources and total bandwidth utilization of the channel. To improve fair resource allocation between users in CRN, this research includes an optimization algorithm. In the optimization algorithm, Secondary Base Stations (SBSs) are represented as N with deployed Secondary Users L_i. Also, with SBSs N primary users are included within the geographical location with K number of primary users. For effective allocation of resources, it is assumed that if PU transmits over a particular channel then SU will not transmit over it. Here, considers the number of the available channel ask with a probability of not transmitting resources defined as ϕ_k.

To detect whether PUs relies upon BSS, for every time slot t energy detector is deployed. The probability of PU within BSS is defined using equation (9):

$$P\gamma^{i}_{\det,k} = e^{-\frac{\alpha_{ik}}{2}} \sum_{b=0}^{B-2} \frac{1}{b!}\left(\frac{\alpha_{i,k}}{2}\right)^{b} + \left(\frac{1+\bar{\gamma}_{ki}}{\bar{\gamma}_{ki}}\right)^{b-1} \times \left[e^{-\frac{\alpha_{ik}}{2(1+\bar{\gamma}_{ki})}} - e^{-\frac{\alpha_{ik}}{2}} \sum_{b=0}^{B-2} \frac{1}{b!}\left(\frac{\alpha_{i,k}\bar{\gamma}_{ki}}{2(1+\bar{\gamma}_{ki})}\right)^{b} \right] \tag{9}$$

where,
b: time product of bandwidth;
$\alpha_{i,k}$: Energy detection threshold in kth channel
γ_{ki}: PU average signal SNR, this is computed as $\gamma_{ki} = P\gamma^{i}_{\det,k}$ with transmitter channel consumption of P_k, with Gaussian noise variance as σ_2. The false probability of PU within SBS within kth channel is computed using Equation (10):

$$P\gamma^{i}_{f,k} = \frac{\Omega\left(b, \frac{\alpha_{i,k}}{2}\right)}{\Omega(b)} \tag{10}$$

where, Ω represents the gamma function. To improve performance spectrum are computed for varying channel conditions of channel, using Equation (11):

$$\alpha^{-k}_{i,j} = \alpha_k \tau^{k}_{ij} \tag{11}$$

In the above Equation (11), i represented the number of users within the channel and j relies on SBS as $j \in S$. The PU trust availability within PU is represented as τ. Based on trust computation ideal state of PU is computed using Equation (12) as follows:

$$\tau^{k}_{ij} = P\gamma\left(i = C^{k}_{o} \middle| j = C^{k}_{o}\right) = \frac{P\gamma\left(C^{k}_{o}\right) j = C^{k}_{o}}{P\gamma\left(j = C^{k}_{o}\right)} \tag{12}$$

where, $P\gamma\left(C^{k}_{o}\right) j = C^{k}_{o}$ denotes the probability of SBS lies within k channel. The channel is estimated based on the consideration of two players PU and SU with partitions of S_1 and $S_2 \in N$ with 1 and $i \in S_2\ f\ i(S_1) \geq f\ i(S_2)$. The PU within SBS within the network with game theory is defined in Equation (13).

$$S_1 \geq_i S_2 \Leftrightarrow f_i(S_1) \geq f_i(S_2) \tag{13}$$

where, S_1 and S_2 represent normal form game theory scenario with preference function of f without any collision as defined in Equation (14):

$$\omega_i = \begin{cases} \alpha_i(S) & \text{if}\left(a_j(S) \geq a_j(S\{i\})\right), \forall_j \in S\{i\} \\ \infty & \text{otherwise} \end{cases} \tag{14}$$

The normal form game theory with a_i the payoff in SBS. Through the calculation of the tradeoff between PU and SU spectrum and resources are allocated between users. For effective allocation of resources between users, this research applies an optimization algorithm iteratively applied. The optimization approach consists of a sequence of stages such as Initialization, selection, Mutation, and Crossover. Within every time slot resources are shared using the proposed MCNF theory. This research uses a greedy bases optimization algorithm adopted an iterative structure is utilized for reducing complexity.

For a computed channel with normal form, the optimization algorithm initializes the process with the assignment of parameters based on available channels and resources as stated in Equation (15).

$$P_{i,j} \sim W\left(lb_j, ub_j\right) \tag{15}$$

where, population size and objective are represented as i=1, 2, 3, ..., N and j=1, 2, 3, ..., D. The lower and upper bounds are denoted as lb and ub with uniform distribution of W. The selection is performed through consideration of unutilized channel estimation expressed in Equation (16).

$$P'_{i,j} \sim W\left(lb_i, ub_i\right) \tag{16}$$

The target population is calculated based on the consideration of initial value and trial population with consideration of fitness values. In the crossover stage, with the greedy selection process resources are updated to the trial population. If the estimated fitness function is minimal value with P_{best} exhibits better fitness value and P_{best} compute global minimizer value. In algorithm 1 guaranteed channel bandwidth and resources are computed. Based on this computation is performed to achieve the best solution. The functionality of the proposed approach is presented in Algorithm 2.

Algorithm 2. MCNF for channel Allocation

Require: maximumiteration, lower-bound, upperbound, N, D, ObjectiveFunction
Ensure: Globalminimum, globalminimizer
function Compute BSA(maxiteration, lb, ub, N, D, ObjectiveFun)
globalminimum = ∞
for i = 1 to N do
for j = 1 to D do
$P_{i,j}$ = rnf.($ub_j - lb_j$) + lb_j. Initialize the population
$P_{i,j}$ = rnd.($ub_j - lb_j$) + lb_j . Old population
end for
fitnessP_i = ObjFun(P_i) .
Initial fitness value of P
end for
for iteration = 1 to maxcycle do
if a < b then
if a < b then
P~ = P | a, b~U(0, 1)
end if
P' = permute(P')
Mutant = F.(P'− P) + P
$map_{1:N,1:D}$ = 1 .
T:=Mutant
for i = 1 to N do
for j = 1 to D do
if mapi,j = 1 then
$T_{i,j}$:= $P_{i,j}$
end if
end for
end for
fitnessT = ObjFunc(T)
for i = 1 to N do
if fitnessT_i< fitnessPi then
fitnessT_i := fitnessP_i
P_i:= T_i
end if
end for
fitnessPbest = min(fitnessP_i)
if fitness best < globalminimum then
globalminimum: = $fitness_{best}$
globalminimizer: = P_{best}
export globalminimizer and globalminimum
end if
end for
end function

5. PERFORMANCE EVOLUTION

In this section, presented about simulation results obtained for the proposed MCNF are presented. The proposed scheme adopts Normal form game theory integrated with an optimization algorithm for resource allocation between PU and SU in CRN. For analysis, the simulation setup consists of 10 relay stations deployed within the area 800×800 m^2. The number of frequency bands considered is 8 with 6 channel availability. The selected bands operate with 10 MHz with a maximal channel transmission capability of 10 W in every band. The maximal transmission range of PU is stated as 250 m with maximal 500 m interference. Total optimization iteration is considered as 1000 with a buffer size of 8k bytes. In Table 1, the simulation parameters for the proposed model is presented:

Table 1. Simulation Parameters

Simulation Parameters	Value Used
Number of Channels	4
Transmission channel	10 W
Noise channel	10^{-10} W
Path Loss Factor	4
Antenna Parameter	3.906
Frequency	10 MHz
Number of Spectrum	8
Transmission Range	250 m
Buffer Size	8k Bytes
Channel Switching Time	1 ms
Primary User (PU) or	25/15

Based on the assigned values the CRN network is constructed. This simulation study is further extended for a varied number of Secondary Users with consideration of running time and PDR rate of network assigned between PU and SU. In Figure 3, the resources allotted for CRN are illustrated. In existing techniques based on detection probability performance is affected, where the proposed MCNF provides an optimization approach for reducing computational complexity. The increase in SUs leads to a reduced number of channels. Further, the proposed MCNF utilizes the available channel completely. The average channel frequency utilization is obtained as 1.65 for a varying number of iterations based on the constructed optimization model in MCNF.

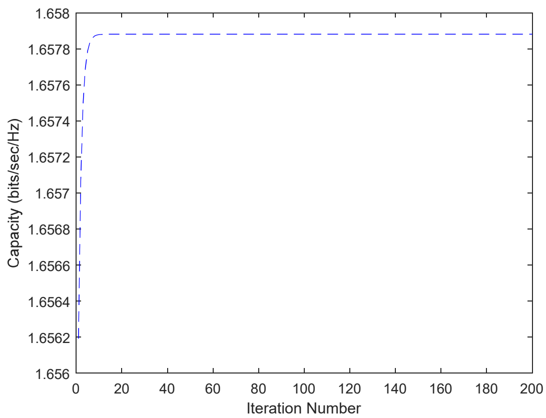

Figure 3. Allocated Channel for assigned frequency

From Figure 3, it is observed that with the increase in traffic volume blocking rate is increased. The proposed MCNF significantly reduces the channel blocking rate with an increase in the volume of resources and an increase in the number of connections within the network. This implies that the proposed MCNF significantly reduces the blocking probability. In Figure 4 presented about frequency allotted for PU and SU are provided.

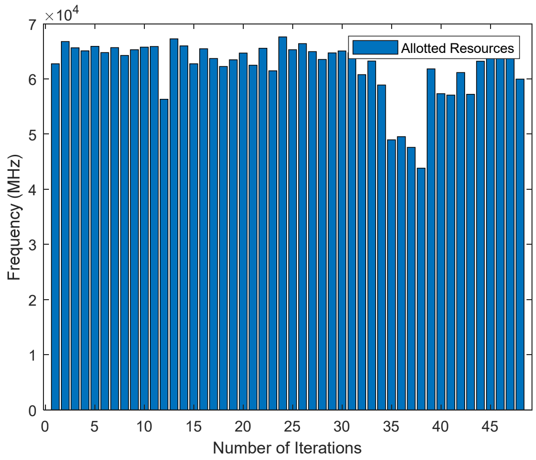

Figure 4. Number of allotted channels

In Figure 4, it is observed that a varying number of iterations for the assigned channel frequency range of 0.07 MHz is utilized for data transmission between PU and SU. Further, it is stated that frequency variation is obtained for every iteration this implies the variation in data traffic. In Figure 5 presented the number of channels utilized by the PU and SU for allocated channels among PU and SU.

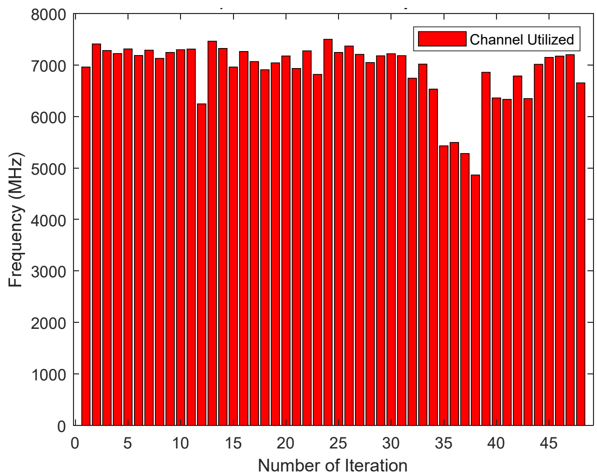

Figure 5. Channel Utilized

The analysis of the simulation exhibited that the proposed technique MCNF effectively utilizes the available frequency for both PU and SU. For varying users, effective frequency bandwidth communication is achieved for 8000 MHz of the frequency band. In figure 6 comparative illustration of the channel allotted for both PU and SU using MCNF is presented.

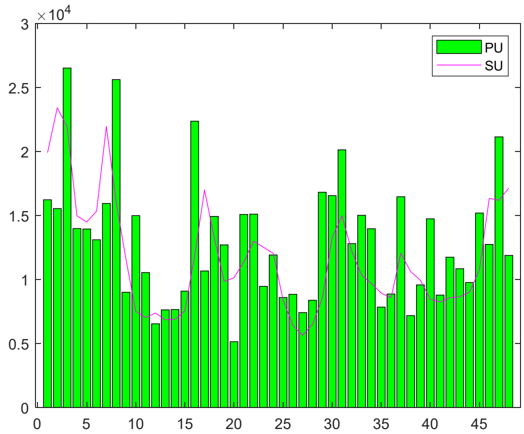

Figure 6. Channel allotted for PU and Sus

From Figure 6, it is observed that an increase in resource utilization level provides increased connections in CRN. In Figure 4 and Figure 5 available connections within the channel are illustrated. Through analysis, it is observed that initial channel connections are similar for an increase in the volume of traffic to the number of connections. The connection disturbance is observed based on the channel condition. The data shows that the network resource allocation of the MCNF game is fair.

From Figure 7, system efficiency is computed for MCNF implies that faster computation of channel resources. If the volume of resources increased to certain level resources within the system are limited with an increase in blocking rate and system efficiency. In Table 2 comparative analysis of the proposed MCNF game theory with existing Monte-Carlo and game, theory algorithms are presented in terms of computation time and PDR is presented.

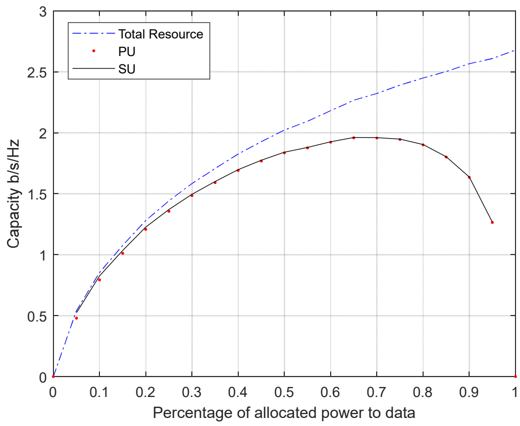

Figure 7. Resources Allocated for SU

In Table 2 comparative analysis of the proposed MCNF game theory with the existing Monte Carlo (MC) and game theory (GT) algorithm is presented in terms of computation time and PDR is presented.

From Table 2, it is observed that for a varying number of users running time is significantly increased. On the other hand, the PDR rate of a varying number of users also increased. To calculate the performance efficiency of the proposed MCNF effective channel is estimated.

Table 2. Comparison of performance of MCNF

Users	Simulation Time (s)			PDR %		
	MC	GT	MCNF	MC	GT	MCNF
50	1.89	1.020	0.97	86.65	98.76	97.64
100	1.92	1.178	1.23	84.83	97.83	96.83
150	1.74	1.605	1.79	89.23	95.67	94.63
200	2.56	1.745	1.92	90.56	91.84	92.78

The simulation analysis of the proposed MCNF approach exhibited that the proposed game theory approach exhibits minimal running time rather than the exiting technique. The analysis is performed for a varying number of users. From the analysis, it is observed that proposed game theory optimization provides reduced running time. The PDR expresses the successful transmission of data for the allotted channel. The PDR analysis exhibits the successful reception of data from source to destination. From the analysis, it is observed that the proposed approach offers higher PDR rather than an existing technique. In Table 3, the overall comparison of the proposed MCNF with game theory in terms of throughput is presented.

Table 3. Comparison of throughput

Users	Throughput		
	Monte-Carlo	Game theory	Monte-Carlo Game
50	0.76	0.87	0.94
100	0.79	0.83	0.90
150	0.83	0.79	0.890
200	0.81	0.81	0.900

The simulation analysis stated that with an increase in users, the simulation time is drastically increased for the proposed MCNF. In analysis, both PDR and throughput fluctuate concerning users. However, this is stated that an increase in users does not impact channel allocation. This implies that the proposed MCNF exhibits fair resource allocation between PU and SU. The higher PDR and throughput lead to increased data transmission with minimal loss. Based on game theory data were transmitted and optimization identifies the unused channel and updates to the base station. From simulation analysis, it is concluded that the proposed MCNF significantly increased PDR and throughput with decreased simulation time, with existing conventional Monte-Carlo and game theory.

6. CONCLUSIONS

This paper focused on improving the performance of CRN in terms of accuracy and spectrum utilization. However, a vast range of techniques are incorporated in resource allocation but resources between PU and SU are a challenging task. This research developed a novel resource allocation technique MCNF for spectrum computation. Based on the estimation of available bandwidth and coverage area of the channel with normal form game theory resources are computed. An optimization search algorithm is applied to reduce the complexity and obtain the optimal global solution. The simulation result shows the improved performance in terms of PDR and throughput with decreased simulation time.

The increase in the running time stated that data were effectively transmitted through the available channel. Also, the increase in PDR rate implies that through effective utilization of channel data are transmitted significantly from PU and SU.

REFERENCES

[1] G.S. KN, M.S. Roopa, R. Tanuja, S.H. Manjula, K.R. Venugopal, "Energy Aware Resource Allocation and Complexity Reduction Approach for Cognitive Radio Networks Using Game Theory", Physical Communication, pp. 101-152, 2020.
[2] Y. Zeng, L. Xu, X. Yang, X. Yi, I. Khalil, "Lightweight Privacy Preservation for Secondary Users in Cognitive Radio Networks", Journal of Network and Computer Applications, pp. 102-652, 2020.
[3] T. Chakraborty, I.S. Misra, "A Novel Three-Phase Target Channel Allocation Scheme for Multi-User Cognitive Radio Networks", Computer Communications, Vol. 15, No. 4, pp. 18-39, 2020.
[4] F. Shang, X. Niu, D. He, H. Gong, X. Luo, "Resource Allocation and Admission Control Algorithm Based on Non-Cooperation Game in Wireless Mesh Networks", Computer Communications, Vol. 15, No. 2, pp. 63-71, 2020.
[5] M. Patnaik, "Secure Proactive Model Predictive Control Based MAC Protocol for Cognitive Radio Networks", Doctoral Dissertation, Masaryk University, Faculty of Informatics, 2018.
[6] H. Anandakumar, K. Umamaheswari, "A Bio-Inspired Swarm Intelligence Technique for Social Aware Cognitive Radio Handovers", Computers and Electrical Engineering, Vol. 71, pp. 925-937, 2018.
[7] A.M. Koushik, E. Bentley, F. Hu, S. Kumar, "A Hardware Testbed for Learning-Based Spectrum Handoff in Cognitive Radio Networks", Journal of Network and Computer Applications, Vol. 10, No. 6, pp. 68-77, 2018.
[8] P. Supraja, V.M. Gayathri, R. Pitchai, "Optimized Neural Network for Spectrum Prediction using Genetic Algorithm in Cognitive Radio Networks", Cluster Computing, Vol. 22, No. 1, pp. 157-163, 2019.
[9] Z. Jin, K. Yao, B. Lee, J. Cho, L. Zhang, "Channel Status Learning for Cooperative Spectrum Sensing in Energy-Restricted Cognitive Radio Networks", The IEEE Access, Vol. 7, pp. 64946-64954, 2019.
[10] N. Basumatary, N. Sarma, B. Nath, "Applying Classification Methods for Spectrum Sensing in Cognitive Radio Networks: An Empirical Study", Advances in Electronics, Communication and Computing, pp. 85-92, 2018.
[11] D.D.Z. Soto, O.J.S. Parra, D.A.L. Sarmiento, "Detection of the Primary User's Behavior for the Intervention of the Secondary User Using Machine Learning", International Conference on Future Data and Security Engineering, pp. 200-213, 2018.
[12] F. Hu, S. Kumar, "Intelligent Spectrum Management Based on Transfer Actor-Critic Learning for Rateless Transmissions in Cognitive Radio Networks", IEEE Trans. Mobile Computer, Vol. 17, No. 5, 2018, pp. 1204-1215.

[13] L. Li, A. Ghasemi, "IoT-Enabled Machine Learning for an Algorithmic Spectrum Decision Process", The IEEE Internet of Things Journal, Vol. 6, No. 2, pp. 1911-1919, 2018.
[14] N. Zhao, F.R. Yu, H. Sun, M. Li, "Adaptive Channel Allocation Schemes for Spectrum Sharing in Interference-Alignment-Based Cognitive Radio Networks", The IEEE Transactions on Vehicular Technology, Vol. 65, No. 5, pp. 3700-3714, 2015.
[15] R.N. Yadav, R. Misra, D. Saini, "Energy Aware Cluster-Based Routing Protocol Over Distributed Cognitive Radio Sensor Network", Computer Communications, Vol. 12, No. 9, pp. 54-66, 2018.
[16] M. Tabassum, M.A. Razzaque, M.N.S. Miazi, M.M. Hassan, A. Alelaiwi, A. Alamri, "An Energy Aware Event-Driven Routing Protocol for Cognitive Radio Sensor Networks", Wireless Networks, Vol. 22, No. 5, pp. 1523-1536, 2016.
[17] N. Tohidi, C. Dadkhah, R.B. Rustamov, "Optimizing Persian Multi-Objective Question Answering System", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 46, Vol. 13, No. 1, pp. 62-69, March 2021.
[18] A. Bujunuru, S. Tadisetty, "Performance Analysis of Full Duplex Energy Harvesting Cognitive Radio Network", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 44, Vol. 12, No. 3, pp. 52-55, September 2020.

BIOGRAPHIES

Bhaveshkumar B. Kathiriya was born in Rajkot, Gujarat, India, 1981. He received the B.E. degree from Saurashtra University, India, the M.E. degree from Gujarat University, India and the Ph.D. degree pursuing from Gujarat Technological University, Ahmedabad, Gujarat, India, all in Electronics and Communication Engineering, in 2003, 2009, and 2018 (onwards), respectively. Currently, he is a Lecturer of Electronics and Communication Engineering at A.V. Parekh Technical Institute, Rajkot, Gujarat, India. His research interests are in the area of wireless communication and spectrum sensing in cognitive radio networks.

D.R. Keraliya was born in Rajkot, Gujarat, India, 1982. He received the B.E. degree from Bhavnagar University, India, the M.E. degree from Gujarat University, India and the Ph.D. degree from Gujarat Technological University, Ahmadabad, Gujarat, India, all in Electronics and Communication Engineering, in 2004, 2006, and 2018 respectively. Currently, he is an Assistant Professor of Electronics and Communication Engineering at Government Engineering College, Rajkot, Gujarat, India. He has 10 publications in reputed journals and holds 19 years of teaching experience. His area of interest is wireless communication.