# Channel Allocation in Cognitive Radio Networks using Evolutionary Technique

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Abstract: Cognitive radio technology provides a platform at which licensed and unlicensed user share the spectrum. In spectrum sharing, interference plays an important role. Therefore, in this work, interference is considered as a parameter for spectrum sharing between licensed and unlicensed users. The authors in this work proposed a novel channel allocation technique using Non-dominated set of solutions according to following objectives: maximum SINR, probability for maximum SINR and maximum free time of channels. The Non-dominated set of solutions has been calculated using Naive and Slow method. The simulation analysis further shows that the proposed technique outperforms the existing technique in terms of throughput and utilization by 65.47% and 47.31% respectively.

## 1 INTRODUCTION

Cognitive radio being an emerging technology, is used for efficient utilization of the spectrum, by introducing cognitive users to search the data transmission opportunities in the absence of primary or licensed users. The architecture of cognitive radio was introduced by J. Mitola in (Mitola, 2000). In addition to this, the signal processing aspects of Cognitive radio was given by Simon Haykin in (Haykin, 2005). Cognitive radio based on the concept of cognitive cycle, has four main functions namely spectrum sensing, spectrum sharing, spectrum decision and spectrum adaptation. In this cycle each function plays an important role.

In spectrum sharing, both licensed and unlicensed users share the spectrum. The coexistence of licensed and unlicensed users is an important issue in spectrum sharing. In (Haykin, 2005; Akyildiz et al., 2006; **?**; Masonta et al., 2013; Tragos et al., 2013; Dhurandher et al., 2009; Ahmed et al., 2014; Dhurandher et al., 2015), the researchers found that interference and bandwidth play an important role in spectrum sharing in cognitive radio networks. In (Haykin, 2005), the author provides the fundamentals of cognitive radio networks and also analyse the impact of interference when primary and secondary users share the spectrum. (Akyildiz et al., 2006) presented a detailed survey of cognitive radio networks and also discussed the issues related to spectrum sharing in detail. (Wang and Liu, 2011) discussed an overview of cognitive radio networks and also studied spectrum sensing and sharing in detail. They discussed various open issues related to spectrum sharing in cognitive radio networks and found that interference is an important parameter in spectrum sharing. (Masonta et al., 2013) focus on various aspects of channel and issues related to spectrum sharing in cognitive radio networks. This paper provides a complete survey of spectrum decisions. (Tragos et al., 2013) reviewed the various techniques related to spectrum assignment in cognitive radio networks. During this study, they described the role of interference in spectrum assignment and found that interference plays a central role in channel allocation in cognitive radio networks in (Tragos et al., 2013). From the works of (Haykin, 2005; Akyildiz et al., 2006; Wang and Liu, 2011; Masonta et al., 2013; Tragos et al., 2013), it is clear that interference plays a key role, when primary and secondary users share the spectrum in any network. Keeping this in mind, the proposed work focuses on minimizing the interference.

The rest of the paper is organized as follows. In Section-II, the related work and motivation towards designing the proposed scheme has been discussed. In Section-III, the system model has been discussed.



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Section-IV presents the simulations and analysis of the result. Finally Section V concludes this work.

## 2 RELATED WORK AND BACKGROUND

(Jiang et al., 2013) presented a scheme for channel allocation and reallocation in cognitive radio networks. They used a multidimensional Markov chain and a multi antenna interface which was connected with only one channel, that was also used for channel allocation. In this paper, the channel allocation behavior in server and non server based system was studied and analysed. The researchers presented an analytic model and defined the performance metrics namely blocking probability, dropping probability and throughput for secondary users. From the simulation analysis, it was found that the proposed scheme improved the performance of cognitive radio system. They considered multiple antennas with one channel only.

(Bayhan and Alagöz, 2014) presented a scheme for best fit channel selection in cognitive radio networks. For this, a Markov model based scheme was developed and used for theoretical analysis of best fit channel selection. Also, the concept of spectrum fragmentation was introduced. The performance of proposed scheme over longest ideal time based channel selection scheme is crucial in terms of spectrum utilization. From the simulation analysis, it was observed that the proposed scheme preformed well and provided significant results in practical situations. In this work, only discrete state space is considered.

(Jalali et al., 2015) presented a dynamic channel access strategy for underlay cognitive radio networks using markov model. The researchers introduced a partial channel occupancy (PCO) mode. The PCO mode provides a partial occupied bandwidth to secondary users, when secondary users co-exist with primary users. They developed a continuous time markov chain based model, that was used to evaluate the performance of licensed and unlicensed networks. Furthermore, a cost against gain analysis were presented and used to check the applicability of the proposed technique for a given traffic scenario. The proposed scheme was well supported by simulation analysis.

(Gelabert et al., 2010) presented a discrete time Markov chain model for spectrum sharing between primary and secondary users with imperfect sensing. The researchers introduced the concept of spectrum awareness implementation approach. Using this approach, the miss-detection and false alarm probabilities were defined and discussed. With the help of these probabilities, a discrete time markov chain model was presented and derived. Based on the Markov model, a scheme was presented and simulated using a system level simulator. Through the simulation analysis, the error in spectrum sensing was analyzed and it was found that the spectrum sensing could be improved by setting the value of interference. The proposed scheme works only for centralized manner not distributed manner.

(Bedeer et al., 2014) presented an approach based on multi objective optimization, that was used to investigate the optimal link adaptation of OFDM based cognitive radio system. The researchers in this work presented an algorithm in such a way that the throughput of the system was maximized and the transmit power was minimized with respect to licensed and unlicensed users. The proposed algorithm was analysed and simulated. From the simulation analysis, it was found that the performance of the proposed algorithm tends to an exhaustive search for the discrete optimal allocations with a reduced computational effort. In this work, an imperfect sensing was considered but in imperfect sensing, the interference constraints may get violated. The interference violation has not been considered in this work.

(Qin et al., 2009) presented the multi objective optimization model using genetic algorithm. To implement the genetic algorithm, the chromosome is used to identify the influence of evolving a radio. Using this chromosome, Multi Objective Cognitive Radio (MOCR) algorithm was proposed. The performance of the algorithm was analyzed and simulated. The result shows that the proposed algorithm provides better results. In this work, only routing constraints were used to design the chromosome. Some other parameters can be used to design chromosome.

(Suliman et al., 2009) presented the analysis of cognitive radio networks with imperfect sensing. The researchers developed two dimensional Markov chain model with the help of false alarm probabilities and missed detection probabilities. Using this model, the behaviour of the network was analysed. In addition, the balance equation from the Markov chain and primary user termination probabilities were also defined and evaluated. From the simulation analysis, it was observed that as per the changes in the arrival rate of primary users, the probability of successful communication for secondary users decreased. In this work, the state equation is defined only for few cases, which may be extended for some other cases as well.

(Wen et al., 2012) presented a Max overall performance algorithm using the concept of genetic algorithm. They defined the Max Sum Bandwidth (MSB) rule, Max Access Fair (MAF) rule and Max Overall Performance (MOP) rule and using these rules and Genetic algorithm, the fitness function was defined. Applying these, an algorithm was proposed by the authors. From the simulation analysis, it was found that the proposed MOP algorithm gave a good overall performance. The researchers considered bandwidth and fairness as the metric and no other metric was considered.

(Wang et al., 2009) proposed a primary prioritized markov approach for dynamic spectrum allocation. They used continuous time markov chain to model the interactions between primary and secondary users. The researchers classified the proposed model into two parts namely primary prioritized CTMC without queue and primary prioritized CTMC with queue. Each of them was further divided into two parts as single user and multi user cases. Each prioritized based model for dynamic spectrum access has been derived and discussed in this work. Through simulation analysis, it was found that the proposed model provided 95% performance gain over a CSMA based random access approach and also attained an optimal tradeoff between spectrum utilization and fairness. The authors did not consider the overhead of the network in the proposed scheme.

(Mahdi et al., 2012) presented an adaptive discrete PSO (ADPSO) algorithm using G.A and PSO. They defined the transmission parameter adaptation in cognitive radio networks and high data rate, less power consumption were consider as the main objectives. To design ADPSO algorithm, the researchers focused on: 1) To reduce the time taken for convergence when optimal set of parameters found. 2) Overcoming the problem of local optimum in PSO and G.A. The ADPSO algorithm was proposed and for evaluating the proposed al-gorithm the multi carrier system was used. From simulation results, it was found that the proposed algorithm performed well in terms of convergence time and the algorithms was also found to overcome the problem of local optimum.

From the aforementioned study, it is observed that the SINR/interference of a channel is one of the important parameters toward channel allocation in CRNs. For better communication, the channel utilization and SINR are to be maximized according to (Xiao et al., 2012; Kumar and Minz, 2015). To overcome the limitations of the schemes discussed earlier in (Jiang et al., 2013; Bayhan and Alagöz, 2014; Jalali et al., 2015; Gelabert et al., 2010; Bedeer et al., 2014; Qin et al., 2009; Suliman et al., 2009; Wen et al., 2012; Wang et al., 2009; Mahdi et al., 2012) and for better utilization of channels, the authors of the work proposed in this paper were motivated to design a Multi Objective based channel allocation scheme in cognitive radio networks.

The proposed work in this paper is along the line of previous research on channel allocation in cognitive radio networks using Markov model by (Teotia et al., 2015) and Multi Objective optimization Techniques by (Kumar, 2015). Here, we presented Non-dominated set of solutions based channel allocation using multi objectives.

## 3 PROPOSED SYSTEM MODEL

Let there be $n$ channels or sub-bands in a frequency band where each channel has $n$ states and there exists SINR for each state at a time instant. Let the states be denoted by $C_0, C_1, C_2, \ldots C_{n-1}$ at time instants $T_0, T_1, T_2, \ldots T_{n-1}$.

Let the state $C_0$ at time instance $T_0$ have SINR $S_0$ with probability $P_{00}$. Let the primary user change the state with probability $P_{11}$.

(Teotia et al., 2015) presented a Markov model based approach for channel allocation with the use of a Markov chain to calculate the probability of SINR at each state.

Using the concept of Markov chain in (**?**), the three parameters namely time, SINR and probability were calculated. These three parameters are shown in Table 1.

Table 1: Parameter for Channel Allocation.

| States | Probability | SINR | Time |
|---|---|---|---|
| $C_0$ | $P_0$ | $S_0$ | $T_0$ |
| $C_1$ | $P_1$ | $S_1$ | $T_1$ |
| $C_2$ | $P_2$ | $S_2$ | $T_2$ |
| . | . | . | . |
| . | . | . | . |
| $C_{n-1}$ | $P_n$ | $S_n$ | $T_n$ |

In (Kumar, 2015), using the parameters in Table 1, a multi-objective function $f(P,S,T)$ is defined as:

$$f(P,S,T) = W_1 f_1 + W_2 f_2 + W_3 f_3 \quad (1)$$

where $f_1$ represents the function of probability, $f_2$ denotes the function of SINR and $f_3$ denotes the function of time and $W_1, W_2, W_3$ denotes the corresponding weights.

A multi-objective optimization problem using Equation 1 has been defined in Equation 2 as:

$$Min \quad f(K) = W_1 f_1(k) + W_2 f_2(k) + W_3 f_3(k) \quad (2)$$

subject to

$$1 \leq K \leq n$$

$$\sum_{i=1}^{3} W_i = 1$$

Where $f_1(k) = 1 - P, f_2(k) = 1 - SINR, f_3(k) = 1 - T$ and $n$ denotes the number of times.

In equation 2, $f_1, f_2, f_3$ are the three objectives according to which channels are allocated to secondary users. There exists a solution space for these objectives which consists of the set of solutions. This set of solutions contains a Non-dominated set of solutions. There exist various techniques to find the Non-dominated set of solutions in this solution set namely Naive and Slow, Kung et. al. approach etc in (Deb, 2001). To calculate Non-dominated set of solutions in this work the authors have used Naive and Slow algorithm in (Deb, 2001; Kumar, 2015; **?**). Using this Non-dominated set of solutions, an algorithm for optimal allocation of channels to secondary users has been proposed.

Algorithm 1: Channel allocation in cognitive radio networks.

**Input:** States $S = S_0, S_1, S_2, S_3 \ldots S_{n-1}$;
Probability of the states
$P = P_{S_0}, P_{S_1}, P_{S_2}, P_{S_3} \ldots P_{S_{n-1}}$;
SINR of channels $SINR = SINR_{S_0}, SINR_{S_1}, SINR_{S_2}, SINR_{S_3} \ldots SINR_{S_{n-1}}$;
Time $T = T_{S_0}, T_{S_1}, T_{S_2}, T_{S_3} \ldots T_{S_n-1}$
**Output:** Channel allocation $K^*$

Obtain the SINR of each state.
**for** *each State* $S_i \in S, i = 1, 2, 3 \ldots n$ **do**
    Calculate the Probability of SINR with the help of markov chain.
    Obtain the time of each state
    Obtain the solution set(K) that optimize $f(K) = W_1 f_1(K) + W_2 f_2(K) + W_3 f_3(K)$
$k^{'} = k$
**while** $|K| \geq 1$ **do**
    Apply Naive and Slow algorithm to obtain the non dominating set($K^*$)
    $k^{'} = k - (K^*)$
Assign channel that exist in $K^*$ to secondary users.
**return** *C.A*

**Proposed Algorithm:** The procedure of the proposed technique is described in algorithm 1.

Let there exist $M = \{M_1, M_2, \ldots, M_n\}$ channels, $P = \{P_1, P_2, \ldots, P_n\}$ primary users and $s = \{s_1, s_2, \ldots, s_r\}$ secondary users in a cognitive radio network. Suppose at a given time instant $t$, $N$ channels are used by primary users. Hence remaining $M - N$ channels are free at that time $t$. The secondary users may use these free channels. There are $s$ secondary users competing for these channels. Now, the secondary user base station initially senses the channels according to the cognitive cycle and then use these channels according to the non-dominated set of solutions. Suppose the secondary user $s_i \in s$ wishes to use the channel $M_i \in M$ , then the secondary user base station first considers SINR, probability and time at that channel. Using the SINR, probability and time, a multi-objective function is formulated in such a way that SINR should be maximum with maximum probability and maximum free time of channels. A solution set has been obtained from the multi-objective function, and Non-dominated set of solutions has been calculated from this solution set using Naive and Slow approach. Now the secondary user base station assigns to be channel $M_i$ for communication to be secondary users$s_i$ based on the non-dominated set of solutions. The channels that have higher SINR and maximum free time is allocated to secondary users. When the free channels are allocated according to Non-dominated set of solutions, remove the Non-dominated set of solutions from the solution set. Now, again calculate the Non-dominated set of solution from the remaining solution set and allocate the free channels according to it. Apply the same procedure on the remaining solution set until the cardinality of solution set is one. This procedure is carried out for all secondary users. Thus, it is observed that the channels that are allocated according to the proposed scheme have less interference and better communication. Hence, the proposed scheme provides an optimal utilization of channels in cognitive radio networks.

## 4 SIMULATION RESULTS AND ANALYSIS

The performance of existing and proposed algorithm is measured by comprehensive simulation study using OMNeT++ network simulator proposed by (Varga and Hornig, 2008). The Cognitive radio network developed for simulation operates in a centralized manner. In the network, base station is the central entity which performs most of the actions and the secondary user base station makes decisions on assigning the channels to the secondary users.

Each primary user is connected to its base station via a channel. All the secondary users are connected to one base station, and each primary user base station is connected to secondary user base station. Primary and secondary user communicate with each other through base station. In the network at a given time, PU can be in generating, receiving or in idle state. At each iteration state of primary user, channel, source and destination user are selected randomly.

**Simulation Parameters:** The performance of both the algorithms is analysed in terms of packet delivery ratio (PDR),throughput, end to end delay (EED), packet flow (PF) and channel utilization by altering the simulation time and number of channels in the network. The PDR represents the ratio of the number of delivered data packets received by the destinations to the number of data packets generated by the sources. The throughput of the network is calculated as average rate of data packets delivered over the network and it is measured in bytes/second. The EED is measured as the time taken in seconds by a data packet to reach the destination. PF is the total number of packets generated in the network per simulation. Channel utilization when plotted against number of channels is measured as average time in seconds for which primary and secondary users uses the channels. Channel utilization when plotted against simulation time is calculated as percentage time in seconds for which channels are used by primary and secondary user per simulation time.

For the simulation of algorithms different topologies have been considered. Number of primary users, secondary users and channels varies between 10 to 50, 20 to 100 and 10 to 50 respectively.

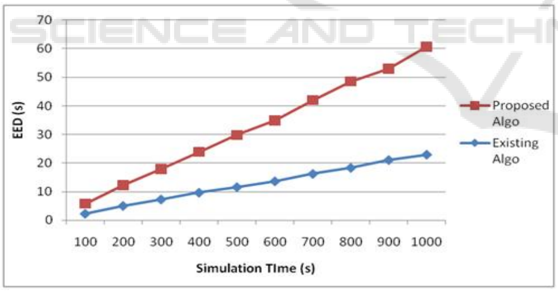


Figure 1: EED vs Simulation Time.

The variation of the existing and proposed algorithm in terms of EED in shown in Figure 1. For both the algorithms the EED increases with increase in simulation time. As the simulation time of the network increases, the packet flow in the network increases. This in turn increases the processing time for each packet hence increasing the EED. Also more number of channels are allocated using proposed algo hence its EED is more than existing algo. By changing the simulation time, the mean EED for existing algo is observed to be 12.85s while for proposed algo it is 20.01s. Thus the percentage increase in EED when channel allocation is performed using proposed algorithm is 56.32%.

From Figure 2 it is observed that PDR for both the algorithms show non uniform behavior with increase in simulation time. There is sharp increase in the PDR of proposed algorithm when simulation time is 1000s. This point represents the minimum interference and conflict experienced by destination nodes which results in delivery of maximum packets. For the existing algorithm mean PDR is 0.182 while for proposed algorithm the mean PDR is 0.297. So during channel allocation using proposed algo the PDR is increased by 63.18%.

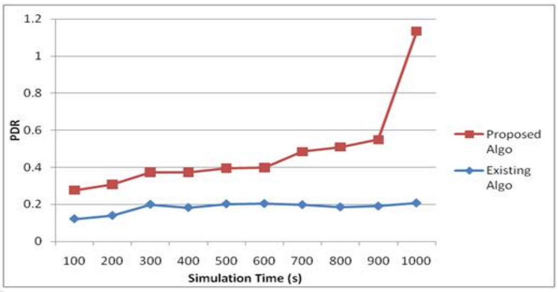


Figure 2: PDR vs Simulation Time.

Figure 3 depicts the variation of throughput (bytes/sec) of both the algorithms with the simulation time. Throughput for the algorithms increases with increase in simulation time. In case of the existing algorithm mean throughput is found to be 0.0168 bytes/sec and for proposed algorithm 0.0278 bytes/sec. Hence when channels are allocated using proposed algorithm, the improved throughput is 65.47%.

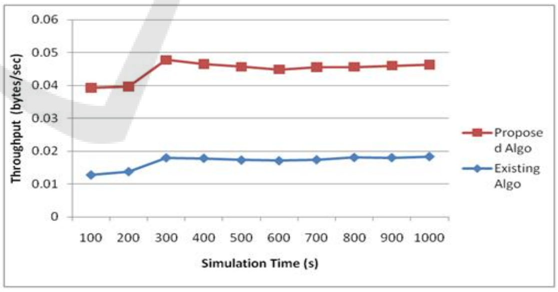


Figure 3: Throughput vs Simulation Time.

Figure 4 and figure 5 shows the relation between channel utilization and number of channels and simulation time respectively. From the graphs it is seen that the channel utilization of the existing and proposed algorithm shows non uniform behaviour with increases in number of channels and simulation time respectively. With respect to number of channels and compared to existing algo the mean utilization is improved by 57.48s for proposed algo. Whereas with respect to simulation time the mean utilization is improved by 0.075s for proposed algo.

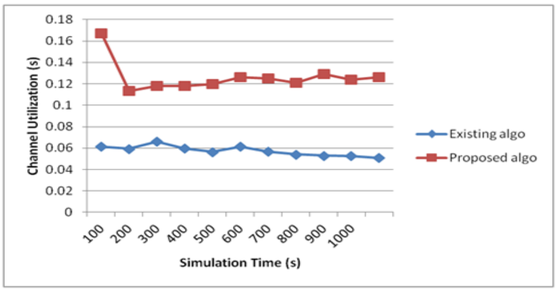


Figure 4: Channel Utilization vs Simulation Time.

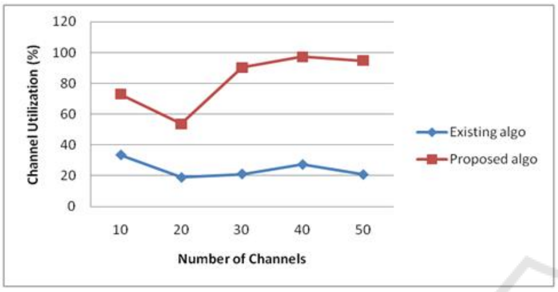


Figure 5: Channel Utilization vs Number of Channels.

Figure 6 shows the variation of PF with simulation time. For both the algorithms with increase in simulation time the number of packets in the network increases linearly. With increase in simulation time, more time is available for users to generate and receive packets thus increasing the packet flow.

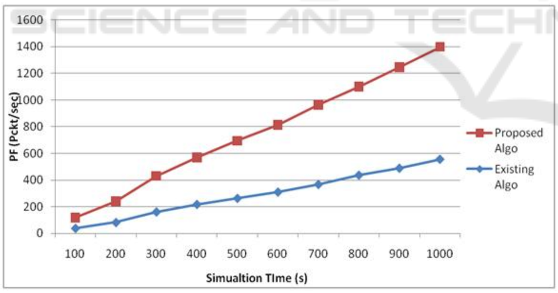


Figure 6: Packet Flow vs Simulation Time.

## 5 CONCLUSION AND FUTURE WORK

In this paper, a novel technique for channel assignment in cognitive radio network is designed in accordance with the objectives: maximum SINR, probability for maximum SINR and maximum free time of channels. The objectives are achieved using Non-dominated set of solutions. To calculate Non-dominated set of solution Naive and Slow method is used. It is observed that the proposed algorithm surpasses the existing algorithm in terms of channel utilization and throughput.

In Future, other approaches can be used to optimize the multi objective optimization problem. Also, any other heuristic approach based algorithm for channel allocation may be developed.

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