

Teaching Learning Based Algorithm for calculating optimal values of Sensing error probability, Throughput and Blocking Probability in Cognitive Radio

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Abstract

We consider Teaching Learning Based Optimization (TLBO) to optimize the sensing error probability, Throughput and Blocking Probability in Cognitive Radio (CR) network. Sensing error probability, Throughput can be optimized by finding the optimal values of false alarm probability and detection probability. Blocking Probability can be optimized by finding the optimum value of number of guard channels. Results of TLBO are compared with Genetic Algorithm (GA) and Differential Evolution (DE) algorithm.

Keywords: Teaching Learning Based Optimization, Cognitive Radio, sensing error probability, Throughput, Handoff Blocking Probability, Differential Evolution and Genetic Algorithm.

1. Introduction

Spectrum scarcity problem can be solved by Cognitive Radio (CR) by utilizing unused channels in the spectrum. There are two types of users in cognitive radio Primary Users (PUs) and Secondary users (SUs). PUs is licensed users to access the spectrum while SUs can access the unused channels opportunistically [1].

Spectrum sensing is used to identify unused channels in the spectrum. As per the guide lines provided by Federal Communications Commission (FCC)[2], SUs can temporarily access the unused licensed channels in the spectrum and they have to vacate the channel when PUs start transmission. There are mainly three types of spectrum sensing methods; they are

- 1) Cooperative spectrum sensing
- 2) Transmitter detection
- 3) Interference based detection.

2. Problem Formulation

To overcome the interference due to hidden node problem cooperative spectrum sensing is used [3]. In Cooperative spectrum sensing, SU uses energy detection method to detect the presence of the PU.

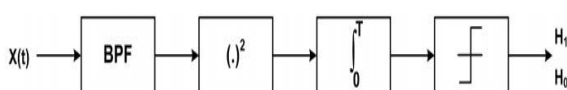


Figure.1. Energy detector

Fig.1 shows the block diagram of energy detector, The received signal $x(t)$ is passed through band pass filter to remove the out of band signal after that signal is squared by square law device followed by finite time integrator, output of the integrator is compared with the threshold determine the presence or absence of PU. Basic hypothesis model for PU detection can be defined as follows

$$H_0: x(n) = w(n) \tag{1}$$

$$H_1: x(n) = y(n) + w(n) \tag{2}$$

Where H_0 is the hypothesis that channel is free i.e. PU is not transmitting, H_1 is the hypothesis that channel is currently occupied by PU, $y(n)$ is signal of PU, $x(n)$ is SU received signal and $w(n)$ is noise.

In centralized cooperative spectrum sensing, fusion centre (FC) collects the sensing information from all SUs to know the presence of the PU. FC of cooperative sensing is shown in Figure.2.

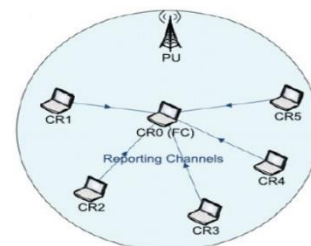


Figure.2. FC of cooperative sensing

Sensing error probability of cooperative spectrum sensing depends on two parameters [4], false alarm probability (P_f) and detection probability (P_d). For best cooperative spectrum sens-

ing P_m should be high and P_f should be low to maximize the throughput of the CR. These two parameters play critical role in spectrum sensing because detection generates interference in PU and false alarm reduce the spectrum utilization of CR.

(a) Sensing Error probability:

The sensing error probability (P_e^j) of jth SU is given by

$$P_e^j = P_f^j * P(H_0) + P_d^j * P(H_1) \quad (3)$$

Where $P(H_1)$ denote the probability of PU presence, $P(H_0)$ denote the Probability of PU absence, P_f^j denotes false alarm probability and P_d^j is detection probability of the jth SU respectively. The total probability of absence and presence of PU is given by

$$P(H_0) + P(H_1) = 1 \quad (4)$$

(b) Throughput:

Let τ_0 and τ_1 denote the transmission rate of the CR system when the PU is idle and active, respectively. τ_0 and τ_1 can be represented as

$$\tau_0 = \log_2(1 + \text{SNR}_s) \quad (5)$$

$$\tau_1 = \log_2\left(1 + \frac{\text{SNR}_s}{1 + \text{SNR}_p}\right) \quad (6)$$

Where SNRs and SNRp denotes SNR of secondary and primary user received at the sensing node. Based on τ_0 , τ_1 and $P(H_0)$, $P(H_1)$ throughput of the CR network can be written as

$$C = \tau_0(1 - P_f)P(H_0) + \tau_1(1 - P_d)P(H_1) \quad (7)$$

(c) Blocking Probability:

We consider Markov chain structure of CR network for modeling Blocking Probability, where N is the number of channels, g is the guard channels and A is the offered load.

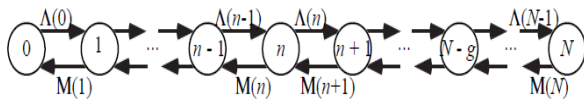


Figure.3. Markov Chain Model of CR network

Considering guard channels and Markov chain structure, Blocking Probability can be represented as [8]

$$Pb = \frac{\sum_{n=N-g}^N \frac{A^{N-g}}{n!} A^{n-(N-g)}}{\sum_{n=0}^{N-g-1} \frac{A^n}{n!} + \sum_{n=0}^N \frac{A^{N-g}}{n!} + A^{n-(N-g)}}$$

Optimization Problems:

Problem 1:

Minimize: Sensing Error probability (P_e^j)

$$\text{Where } P_e^j = P_f^j * P(H_0) + P_d^j * P(H_1) \quad (5)$$

$$\text{Subject to } 0.1 \leq P_f^j \leq 0.9; 0.1 \leq P_d^j \leq 0.9 \quad (6)$$

Problem 2:

Maximize: Throughput (C)

$$\text{Where } C = \tau_0(1 - P_f)P(H_0) + \tau_1(1 - P_d)P(H_1) \quad (7)$$

$$\text{Subject to } 0.1 \leq P_f \leq 0.9; 0.1 \leq P_d \leq 0.9 \quad (8)$$

Problem 3:

Maximize: Blocking Probability (P_b)

$$Pb = \frac{\sum_{n=N-g}^N \frac{A^{N-g}}{n!} A^{n-(N-g)}}{\sum_{n=0}^{N-g-1} \frac{A^n}{n!} + \sum_{n=0}^N \frac{A^{N-g}}{n!} + A^{n-(N-g)}}$$

Subject to $g < N$

3. Solution Algorithm

We considered TLBO algorithm to solve the three optimization problems of CR network.

- **Problem 1:** Find optimized values of P_f and P_d to minimize Sensing Error probability
- **Problem 2:** Find optimized values of P_f and P_d to maximize Throughput.
- **Problem 3:** Find optimized value of g (number of guard bands) to minimize Blocking Probability.

We also considered popular evolutionary algorithms GA and DE algorithm to compare the optimization results of TLBO.

GA was proposed by John Holland in 1970. The main functions of GA are selection; crossover; mutation [5].

- DE was proposed by R.Storn and K.Price in 1997 [6]. The basic operations of DE are mutation, recombination and selection.
- TLBO algorithm was introduced by Rao et al. in 2011[7]. The basic operations of TLBO are teacher phase and learner phase.

TLBO algorithm can be implemented with less number of parameters such as population size, number of design variables where as GA requires additional parameters probability of crossover, probability of mutation and DE requires scaling factor, crossover rate. The performance of the algorithms can be highly affected by small changes in the parameters.

TLBO depends on an innovative learning approach i.e. the past best student in the class becomes the teacher from the next iteration. Then other students can learn from him or from other friends to improve the knowledge. Group of students in the class treated as population and subjects are equivalent to design variables of the optimization problem. The main functions of TLBO algorithm:

- Initialization:** generate the random population based on population size (group of students) and design variables (different Subjects).
- Teacher Phase:** teacher shares the knowledge among the students and increases the mean result of the population.
- Learning phase:** Student interacts with other students randomly to increase their knowledge.
- Repeat:** repeat the steps c and d until it gives minimum optimum value of sensing error probability P_e^j .

Table 1: Parameters used to simulate TLBO, GA and DE

Parameters	Values
Population Size	50
Number of Iterations	100
Crossover Probability (GA)	0.25
Mutation Probability (GA)	0.078
Scaling Factor(DE)	0.8
Crossover Rate(DE)	0.9

4. Simulation Results

To simulate objective function with GA, DE and TLBO, we used MATLAB software on Intel quad core processor, 4G RAM with parameter values given in Table 1.

Results of Problem1:

The minimum of the function Sensing Error Probability is obtained and the convergence of the solution is shown in Fig 4. The optimum value of P_f and P_d for Sensing error probability obtained by TLBO, DE and GA are shown in below table 2.

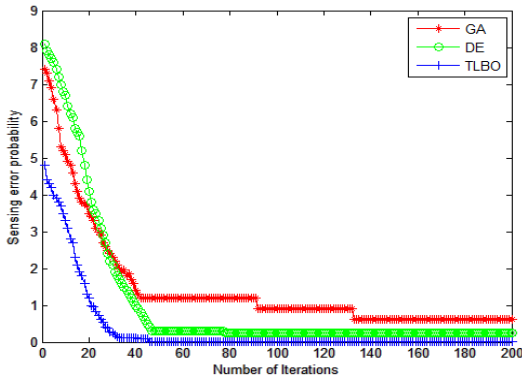


Figure .4 Sensing error probability Vs No. of iterations

Table 2: Comparative Analysis of TLBO, DE and GA

The minimum sensing error probability $P_e^j = 0.021$ obtained by TLBO when false alarm probability (P_f^j) = 0.03 and detection probability (P_d^j) = 0.27, it indicates that optimum value of P_d^j is higher than optimum value of P_f^j .

Methodology	$P(H_0) = 0.2;$ $P(H_1) = 0.8$		$P(H_0) = 0.5;$ $P(H_1) = 0.5$		$P(H_0) = 0.8;$ $P(H_1) = 0.2$	
	P_e^j	No. iterations	P_e^j	No. iterations	P_e^j	No. iterations
TLBO	0.021	44	0.0	47	0.029	42
DE	0.13	78	0.2	81	0.1	73
GA	0.95	133	0.7	146	0.83	126

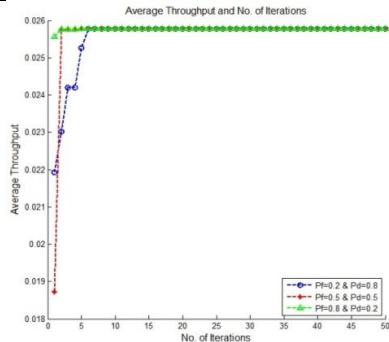


Figure.7. SNRp=20db, SNRs= -10db

Results of Problem2:

The maximum of the function Throughput is obtained and the convergence of the solution is shown in Fig. The optimum value of P_f and P_d for Throughput obtained by TLBO are shown in below table 3.

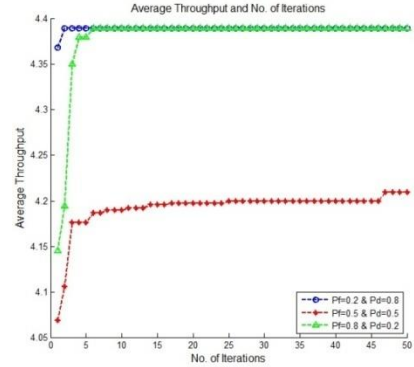


Figure.5.SNRp=20db,SNRs=15db

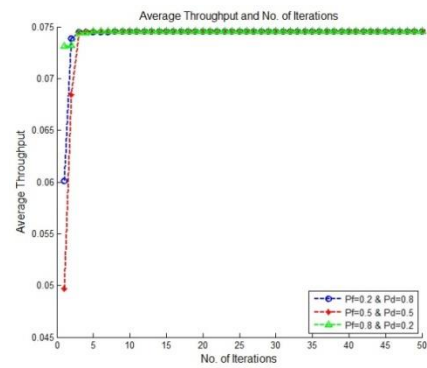


Figure.6.SNRp=20db,SNRs=-15db

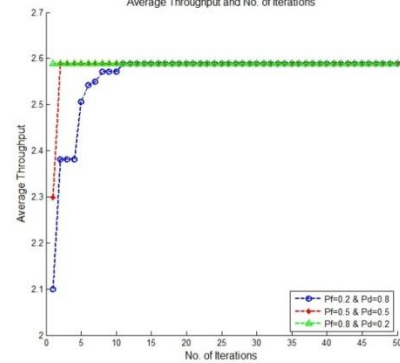


Figure.7.SNRp=20db,SNRs=10db

The objective function of Throughput is simulated with four different combinations of SNR values and three different combinations of PU probability $P(H_0)$ and $P(H_1)$. As shown in Table 3 Throughput is maximum when SNRp= 20db, SNRs=15db and $P(H_0) = 0.2;$ $P(H_1) = 0.8$

SNR of PU and SU	$P(H_0) = 0.2; P(H_1) = 0.8$		$P(H_0) = 0.5; P(H_1) = 0.5$		$P(H_0) = 0.8; P(H_1) = 0.2$	
	Throughput	Number of iterations	Throughput	Number of iterations	Throughput	Number of iterations
SNR _p = 20db, SNR _s =15db	4.397	3	4.21	3	4.39	4
SNR _p = 20db, SNR _s =-15db	0.074	3	0.074	5	0.074	4
SNR _p = 20db, SNR _s = 10db	2.58	12	2.58	3	2.58	1
SNR _p =20db, SNR _s =-10db	0.0258	1	0.0258	1	0.0258	1

Results of Problem3:

The minimum of the function Blocking Probability is obtained and the convergence of the solution is shown in Fig. The optimum value of *g* for Blocking Probability obtained by TLBO, DE and GA are shown in below Figure.8.

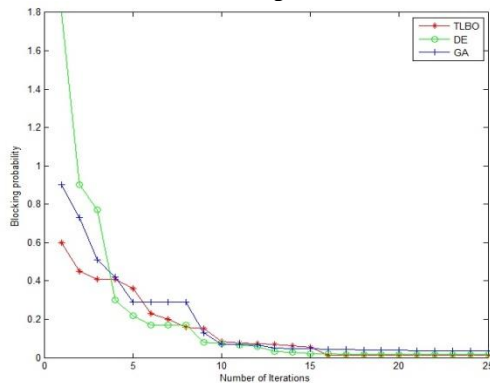


Figure .8 Blocking Probability Vs No. of iterations

The objective function of Blocking Probability is simulated with number of channels N=20. As shown in Table 4, TLBO algorithm gives the minimum value i.e. 3 guard channels are required to minimize the Blocking Probability in CR network.

Table 4: Comparative Analysis of Blocking Probability

Methodology	Blocking probability	Number of guard channels(<i>g</i>)	Number of iterations
TLBO	0.014	3	16
DE	0.017	5	17
GA	0.035	5	21

5. Conclusions

To increase the performance of CR network, we considered three optimization problems and determined the optimum values of P_f , P_d and *g* by using TLBO successfully and compared the results of TLBO with GA and DE Simulation results show TLBO gives better optimum solution compared to Genetic Algorithm (GA) and Differential Evolution (DE).

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