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Spectrum Sensing By Cognitive Radio with Hybrid Metaheuristics

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***Abstract:** Range detecting instruments empower Cognitive Radio systems to recognize Primary clients (PUs) and use range openings for Secondary client (SU) transmission. In this paper, exceptionally effective cost improvement of Particle Swarm Optimization is proposed i.e. PSO-ACO. Hybridization of Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) essentially builds the location rate as Ant Colony Optimization (ACO) quickens from false minima which diminishes the false minima. With this, throughput increments upto 92% and mistake rate lessens upto 10-3. PSO-ACO hybridization altogether beats and fastly unite as a result of ACO advancement.*

***Keyword:** Cognitive Radio (CR), Primary User (PU), Secondary User (SU), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Probability of False alert (PFALSE), Probability of discovery (PDET), and throughput.*

I. INTRODUCTION

As there are limited number of spectrum resources, so efficient utilization of these resources is a necessity. Cognitive Radio is a technique that is used for this purpose. There are two types of spectrum users -Primary and Secondary. Primary user has a license of spectrum while secondary user is an unlicensed user. When the spectrum of Primary user is idle, se condary user can use this spectrum until the primary user is inactive but when the primary user becomes active, the secondary user must immediately vacate the spectrum of the primary user so that there is no interference to the primary user. The spectrum which is idle at a time is called spectrum hole. Cognitive Radio has three main tasks- Sensing, Reasoning, and Learning. In sensing, Cognitive Radio senses its RF environment to detect the spectrum holes and to detect the presence of the primary user. Cognitive radio has a fixed time frame in which it works.

The time frame of Cognitive Radio is divided into two parts - sensing time and transmission time. Sensing time is the time in which CR senses its environment and transmission time is the time in which CR transmits the data. If sensing time of the CR is large then there will be less transmission time, hence there will be small throughput. If transmission time of CR is large then there will be small sensing time. With this, there can be undetected active Primary user and there will be interference to the Primary user. Hence, there is a tradeoff between sensing time and transmission time. There should be some optimal sensing time at which there is maximum possible throughput provided there is no interference to the Primary user. To find this optimal sensing time, we can use various optimization techniques and also hybridization of these techniques. In this paper, we will discuss the hybridization of Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) to optimize the sensing time of CR. We will also compare the results of PSO-ACO hybridization with results of PSO and results of maximum likelihood technique.

Particle Swarm Optimization (PSO) is an optimization technique that is based upon bird flocking and fish schooling. Swarm is the collection of particles. There is some objective function whose value has to be optimized with PSO. The optimized value of the objective function will be some point in the search space. Every particle moves in the search space to find the point at which objective function is optimized. At any point of time, every particle has some position and velocity in the search space. Initially, positions and velocities of particles are randomly assigned. After each iteration, positions and velocities of particles are updated using equations 1 and 2. Every particle in PSO has its local best position and the global best position of the swarm. The global best position of the swarm is the position of the particle which is more close to the optimal value. All the particles will move towards the global best position as it is close to the optimal value. The global best position of the swarm will be updated if some other particle's position becomes more close to the optimal value. Now, this particle's position will become the global best position of the swarm. All the particles will move towards this updated global best position. In this way, at some point in time, all the particles will converge at one point and this point will give the optimal value of the objective function.

$$V_{i,d}(t+1) = \alpha(t)V_{i,d}(t) + \beta_p ran_p(t)(persbest_{i,d}-P_{i,d}(t)) + \beta_g ran_g(t)(globest_d-P_{i,d}(t)) \quad (1)$$

$$P_{i,d}(t+1) = P_{i,d}(t) + V_{i,d}(t) \quad (2)$$

Where $V_{i,d}$ and $P_{i,d}$ is the velocity and position of particle I , dimension d at iteration t+1.$\alpha(t)$ is the weight that tracks the history of velocity, $\beta_p ran_p(t)$ and $\beta_g ran_g(t)$ are the random factors, $persbest_{i,d}$ is the Personal Best of particle I for dimension d and globest is the Global Best of the swarm for dimension d.

Ant Colony Optimization (ACO) is an optimization technique that is used by ants to find the shortest path between food and nest. Ants communicate with each other through some kind of secretion called Pheromones. While moving, every ant secretes its pheromones on the path. These pheromones evaporate after some time. Every ant finds the solution of the problem iteratively. At every iteration, each ant moves from one position to another position to complete the partial solution. For an ant, the probability of moving from x to y depends upon two factors:

(1) The attractiveness of the edge: It is the prior desire of the move and is calculated by some heuristic. Normally, it is the reciprocal of the distance between x and y.

(2) Pheromone density of the edge: It is a number of the pheromones on the edge of x and y.

An ant moves from x to y with probability as follows:

$$P_{xy} = \frac{(Pm_{xy}^{\alpha})\,(\lambda_{xy}^{\beta})}{\Sigma_{z \in allowed\ x}(pm_{xz}^{\alpha})(\lambda_{xz}^{\beta})}$$

Where Pm_{xy}^{α} is the pheromone amount deposited on the transition from x to y, λ_{xy}^{β} is the attractiveness for the transition from x to y (normally $(1/d_{xy})$ where d is the distance between x and y), $\alpha \geq 0$ is the parameter that controls the pheromone amount and $\beta \geq 1$ is the parameter that controls the attractiveness.

On finding food, ants take food and returns back to the nest through the same path. An ant that will reach the nest first has chosen the shortest path as it comes back in the shortest period of time. The Pheromone density on this path will higher than the other paths as it is shortest and ant has deposited the pheromones while going and returning. On the longer paths, when the ants will return, the previous pheromones will get evaporated and the pheromone density on these paths will be lower than the shortest path. Now, the next ants will choose the shortest path as the pheromone density on this path is more than the longer paths. These new ants will further increase the density of the pheromones on the shortest path. Pheromones on the paths are updated by using the following formula:-

$$Pm_{xy} = (1-\Phi)\, Pm_{xy} + \textstyle\sum_k \Delta Pm_{xy}^{k}$$

Where Pm_{xy} is the pheromone amount on the transition from x to y, Φ is the evaporation coefficient of pheromones, ΔPm_{xy}^{k} is a number of pheromones that kth ant deposited on the transition from x to y.

At one point of time, pheromone density of the longer paths will become zero and all ants will go through the shortest path.

Hybridization of PSO and ACO optimize the decision of secondary user for spectrum sensing. When the Primary user is idle then lot of secondary users sense the channel of the primary user. If a secondary user equipped the channel then other secondary users will detect false which reduces the throughput and increases the false detection. Particle Swarm Optimization (PSO) is used to optimize the decision but it still has high-cost convergence problem which is reduced by ant colony optimization by optimize the cost of PSO by fast convergence.

System Model

There are two types of sensing in Cognitive Radio Networks- preliminary coarse sensing and fine sensing. In preliminary course sensing, CR senses its environment to detect the spectrum holes. After the spectrum holes are detected, CR performs fine sensing to detect the presence of the Primary user. CR has fixed time frame to perform fine sensing and to transmit the data to the receiver. The time frame of CR is divided into sensing time and transmission time. Let X_f is the frame duration, X_s is the sensing time and X_t is the transmission time of the CR, then

$$X_f = X_s + X_t \quad (5)$$

As there is a tradeoff between sensing and transmission time, an optimal sensing is a necessity at which there is a maximum possible throughput and minimum interference to the PU as well.

There is two hypothesis of the sensed signal S[n] as follows:

$$\begin{cases} H0: N[n] & \text{if primary user is inactive} \\ H1: gP[n] + N[n] & \text{if primary user is active} \end{cases}$$

where n=1,....,Y; Y is the no. of samples, g is the channel gain that is 0 under H0 and 1 under H1. N[n] is the noise. N[n] has zero mean and variance σ_n^2. P[n] is the Primary User signal and every sample is identically distributed having mean = 0 and variance = σ_p^2.

The energy detector collects the signal samples S[n] and provides the output D, which is used for decisions:

$$D = \frac{1}{Y}\sum_{n=1}^{Y}(S[n])^2 \quad (6)$$

P_{det} and P_{false} are the probability of detection and probability of false alarm respectively. The probability of detection is the probability of detecting PU when it is actually present and the probability of false alarm is the probability of detecting the PU when actually it is not present. Let the threshold for detecting the PU is T then,

$P_{det} = P(D>T|H1)$, $P_{false} = P(D>T|H0)$

$P_{det} = Q(\frac{T-\mu_1}{\sigma_1^2})$, $P_{false} = Q(\frac{T-\mu_0}{\sigma_0^2})$

II. SIMULATION AND RESULTS

Figure 1 shows the graph of Probability of false alarm and Probability of detection. This graph shows that probability of detection is higher and the probability of false alarm is lower for PSO- ACO optimization. PSO detection does not increase as much as PSO with ACO because PSO with ACO accelerated from false minima but PSO does not reduce false minima part.

Figure 2 shows the graph of throughput and probability of false alarm. In this graph, throughput increases as false alarm increases in all cases but there is a significant difference between normal and PSO with ACO because in normal, there is no intelligent optimization . Between Intelligent algorithms i.e. PSO and PSO with ACO, PSO with ACO shows the better impact on throughput than PSO.

Figure 3 shows the graph between throughput and sensing time. At a fixed sensing time, the throughput of PSO with ACO is higher than PSO and normal. The line with stars shows the ideal behaviour between throughput and sensing time.

Figure 4 shows the graph between total error rate and threshold with PSO and Figure 5 shows the graph between total error rate and threshold with PSO-ACO. PSO-ACO reduces error rate more than 10^{-3} and PSO reduce error rate only more than 10^{-2}.

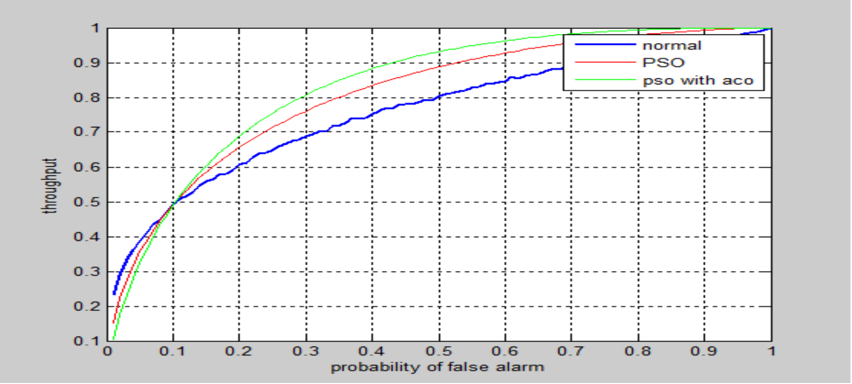

Figure1. "Graph between Probability of false alarm and throughput".

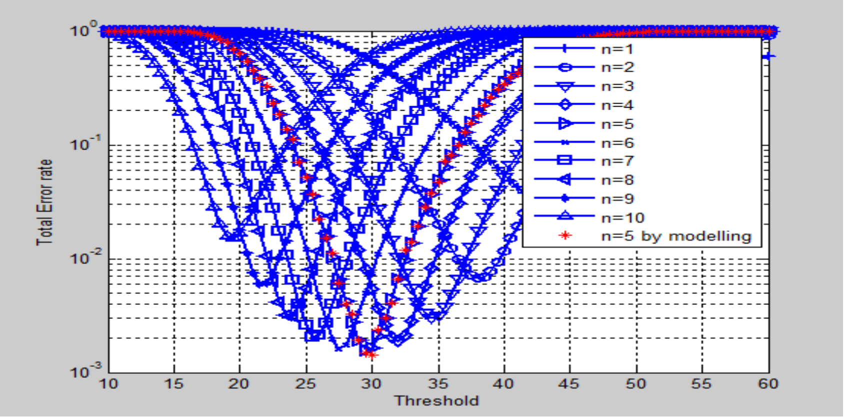

Figure2. "Graph between Total Error rate and Threshold of PSO".

CONCLUSION

In this paper upgrade the choice by auxiliary client for range detecting. In intellectual radio auxiliary client dependably rely on upon essential client for channel however when essential client free then a significant number of optional client sense the channel.If optional client prepared channel first and other auxiliary client recognize false at that point diminish the throughput and increment the false location for that improve the choice by met heuristic like molecule swarm optimization(PSO) yet despite everything it have high-cost merging issue which lessens by subterranean insect province enhancement by streamline the cost of PSO by quick union that is the reason increment the throughput and it will increment as false recognition increment in light of the fact that PSO –ACO advance cost advance as increment the identification time. In figure4 PSO-ACO diminishes mistake rate more than 10-3 and PSO decreases blunder rate just more than 10-2.In figure 1,2&3 throughput and false identification, it has indicated PSO-ACO perform well, so by these outcomes close PSO_ACO perform well than PSO.