Modelling of Spectrum Handover Scheme using Particle Swarm Intelligence in Cognitive-radio Networks

Meha Bansal, Roopali Garg

Abstract: ***Cognitive radio is a self adaptive network technology, which helps in detecting idle channels within a spectrum range. Cognitive radio has four functionalities namely Spectrum sensing, decision, sharing and mobility. This research work is in the domain of spectrum mobility. Spectrum mobility deals with motion of unlicensed users in the network. Unlicensed users are the unauthorized users of cognitive radio networks who have lower priority than licensed ones. Major functionality of spectrum mobility is spectrum handover and connection management. In cognitive radio, the method of switching channels is termed as spectrum handover. Whenever a high priority user appears to occupy its spectrum band, that is already been utilized by a low priority user, spectrum handover takes place. During this process, a lot of handover delay occurs, which results in increasing the total service time of transmission. Total service time of spectrum handover means amount of time required to perform successful handover during spectrum mobility stage in cognitive-radio-networks. To decrease this total service time of spectrum handover we have utilized the concept of Particle Swarm Intelligence and M/G/1 queuing model. The parameters used for the purpose are swarm size, arrival rate, service rate, acceleration coefficients, processing time and channel switching time. Swarm size indicates the number of particles present in a swarm. In this research work, value of swarm size is varied to see its effect on total service time of spectrum handover process. Numerical results demonstrate that by increasing the value of swarm size, total service time decreases.***

Index Terms: Arrival Rate, Primary User, Secondary User, Service Rate, Swarm Size

I. INTRODUCTION

From recent years, wireless industry is been developing very fast. There is a drastic surge in the requirement of spectrum based devices plus services. The current bandwidth allocation approach implemented by government has resulted in poor utilization of the available spectrum, which has resulted in a problem of spectrum insufficiency [1]. Statistics provided by Cisco states that the traffic of mobile data will increased 17-fold between 2017 and 2022 [2]. Therefore, there is need of broader bandwidth. 5G is a revolutionary network technology in communication era. It is expected that, 5G technology can solve this problem by supporting more than ten thousand times of data traffic [3]. 5G network will provide greater bandwidth as compared to the existing technologies such as 2G, 3G, and 4G. With increased bandwidth, more people will be able to use data services at higher speeds.

Mitola presented the concept of cognitive radio in 1999. The users of cognitive radio networks are Primary users (PU) and Secondary users (SU) [4]. Primary users are the licensed users and secondary users are the unlicensed ones. The primary users have high precedence than secondary users to utilize the spectrum band, as they possess a legal license over the spectrum [5].

Later, a new technology named 'Dynamic Spectrum Access' is developed using cognitive-radio technique. This technique gives the secondary user an authority to access the idle spectrum band of primary user by avoiding disruption on the emergence of primary user at later stages [6].

Cognitive radio has four stages namely Spectrum sensing, Spectrum decision, Spectrum sharing and Spectrum mobility [7]. In spectrum sensing stage, the cognitive radio sense vacant channels within the spectrum range. Spectrum decision helps to detect best available channels in the spectrum [8]. Spectrum sharing performs the task of maintaining the quality of service throughout the process and avoids collision between secondary users present in the network [9]. Spectrum mobility occurs due to the constant emergence and departure of licensed users in the network. Whenever a primary user comes to occupy its spectrum band that is already been occupied by the secondary user, spectrum-mobility occurs [10]. In this case, the secondary user has to find other idle spectrum band, which suits its QoS requirements to resume its transmission process. Spectrum mobility helps to provide seamless communication requirements by providing fast and smooth transition throughout the process [11]. This research work has its focus on spectrum mobility in CR.

Spectrum Handover is a process of switching data communication from present channel to other idle channel [12].

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Whenever primary user arrives in its spectrum, secondary user discontinues its ongoing transmission and starts detecting a free channel in the spectrum band available. After detecting the appropriate channel according to its requirements, it has to switch from existing channel to the other unused channel available in the spectrum band [13].

During the handover process, the channel that offers shortest handover delay is selected as the target channel [14]. The to and fro switching of target channels causes degradation in the efficiency of the network. Due to this, the performance of secondary users is also reduced and the total time of the transmission increases. As a result of this situation, the main purpose of spectrum mobility is to diminish the performance degradation of spectrum handover process by facilitating fast and smooth transition.

Various spectrum handover strategies are Non handover strategy, Proactive handover strategy, Reactive handover strategy and Hybrid handover strategy. In Non handover strategy, secondary user constantly detects the emergence of primary user in the channel. When primary user arrives, the secondary user has to halt its transmission and has to wait for primary user to leave. After the departure of primary user, secondary user restarts its communication process. In Proactive handover strategy, the secondary user keep sensing the arrival of primary user consistently in advance manner. The handover delay in this strategy is based upon the traffic pattern of primary user.

Reactive handover strategy determines the target channel after the event of handover triggering. This strategy faces a lot of handover delay while performing spectrum sensing. In Hybrid handover strategy, combination of both reactive and proactive technique is used. In this strategy, spectrum sensing is been performed using proactive technique and after that handover is triggered using reactive technique. Also, the handover delay faced by this strategy is very less as compared to above discussed strategies.

II. RESEARCH METHOD

A. M/G/1 queuing model

In this section, Pre-emptive-resume-priority M/G/1 queuing model is been used to depict the usage of spectrum among primary and secondary-users. This model estimates the spectrum utilization in terms of traffic arrival rate, service time and transmission latency. Some major properties of this model are such as (1) Primary user can interrupt the ongoing communication of secondary user any time because they have pre-emptive priority over the spectrum. (2) After the departure of primary user, a secondary user can resume its uncompleted transmission rather transmitting the whole packet again. (3) All the secondary-users of the spectrum can access the channel on first come first serve basis.

Therefore, on the basis above said properties, the primary-users are been placed on higher priority queue whereas secondary-users are placed on lower priority queue. Whenever a primary-user interrupts a secondary-user, secondary user has two choices either it can stay on the present channel and wait for the primary-user to leave or can change its transmission from current operating channel to another channel available in network. The symbols and definitions of this model are as follow.

1. The arrival rate of primary users and secondary-users is been denoted by λ_p and λ_s respectively have k default channels. The service rate of primary users and secondary users is been denoted by μ_p and μ_s. Their corresponding average service time is been represented by $E(X_p)$ and $E(X_s)$ respectively.

2. Let $E[D]$ as average handover delay of secondary user. The average no. of interruptions while transmitting a secondary-packet in a period of $E[Xs]$ is given by $E[N]$,

$E[N] = \lambda_p E[X_s]$

3. In case of stay situation, Yp gives the average handover delay or busy period.

$$Y_p = \frac{E[X_p]}{1 - \lambda_p E[X_p]}$$

4. In always change situation, the handover delay is the sum of waiting and channel-switch time of secondary user and is been represented by $(W_s + t_s)$.

5. Let processing time as t_p

Where t_p= channel switching time + channel sensing time.

6. Total service time of secondary users is been denoted by S,

$S = E(X_s) + E[N]E[D]$

For always stay situation,

$E[S_{stay}] = E[X_S] + E[N]Y_p$

For always change situation,

$E[S_{change}] = E[X_S] + E[N](W_s+t_s)$

Optimal total service time is been denoted as:

$$S = \begin{cases} E[S_{stay}] & , \quad Y_p \leq W_s + t_s \\ E[S_{change}] & , \quad Y_p \geq W_s + t_s \end{cases}$$

Therefore, the above results signify that, if sum of the waiting time and channel switch time is greater than busy period, the disrupted secondary user will choose to stay at current channel. On the other hand, if the sum of waiting time and channel-switch time is smaller than the busy period, the disrupted secondary user will choose to change its frequency operation from current channel other idle channel.

7. Consider a case when a secondary user, which is disrupted by a primary user now has to search a random target channel amongst all the channels available in the spectrum can be given by

$$E[S_r] = E[X_s] + \frac{E[N]\,Y_p}{2} + \frac{E[N]\,(W_s + t_s)}{2}$$

Using above equation, the total service time for reactive handover strategy is

$E[S_{reactive}] = E[X_s] + W_{s,reactive}$

Where the waiting time for secondary user is

$$W_{s,reactive} = \frac{\lambda_p(t_p\,\mu_s + \lambda_p\mu_s E[X_p]^2) + (\lambda_s - \lambda_p t_p\,\mu_s)E[X_p]}{\mu_s^{\,2}(1 - \lambda_p E[X_p])}$$

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In case of proactive handover strategy the total service time is

$$E[S_{proactive}] = E[X_s] + E[N](W_{s,proactive} + t_s)$$

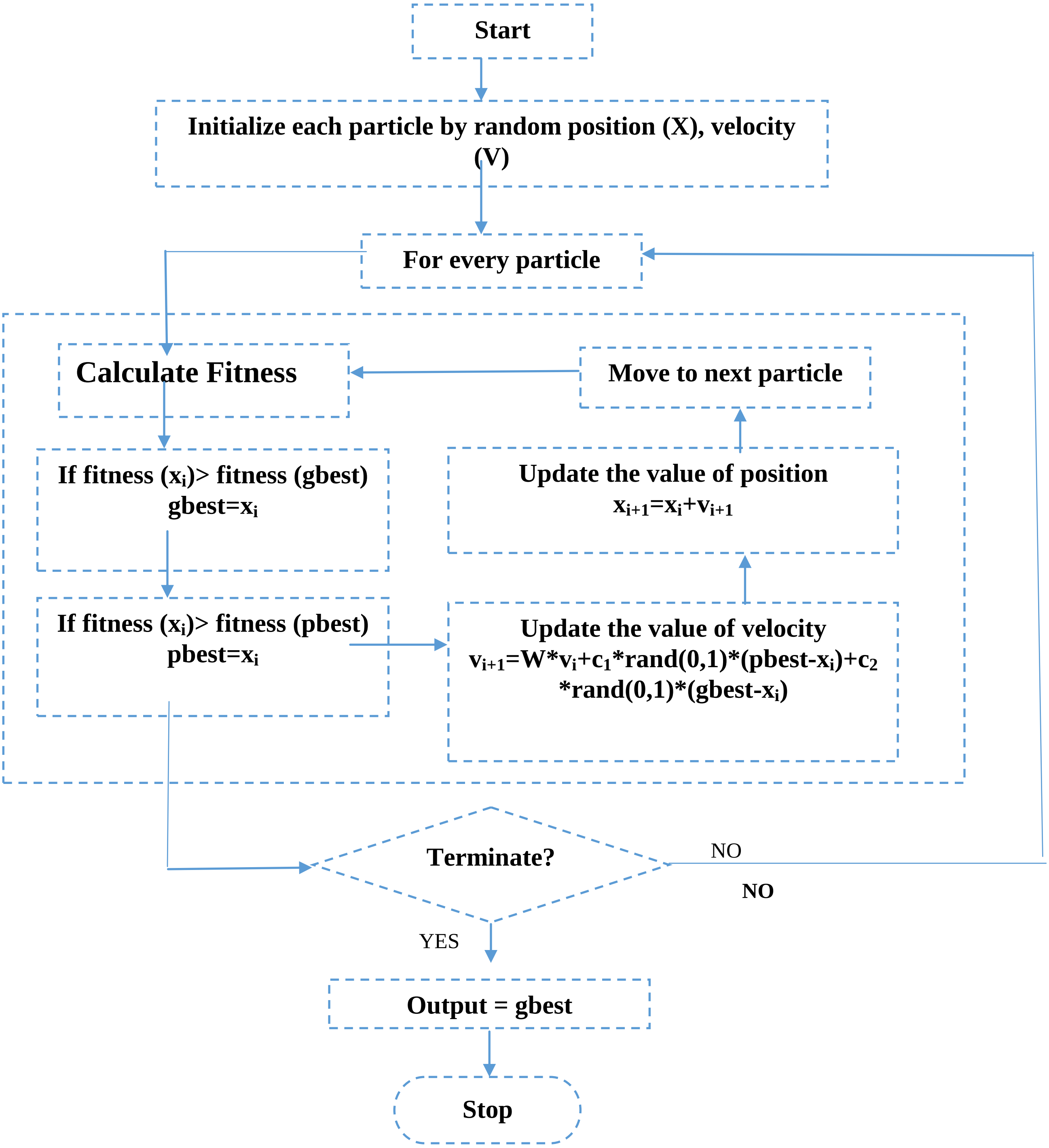

Fig. 1 Schema of PSO. [15]

Where the waiting time for secondary user is

$$W_{s,proactive} = \frac{0.5\,\lambda_p E[X_p]^2 + \frac{\lambda_s}{(\lambda_s + \lambda_p)\mu_s} + \frac{\lambda_p{}^2 E[X_p]^2}{2(1-\lambda_p E[X_p])} E[X_p]}{1-(\lambda_p E[X_p]) - (\lambda_s E[X_s])}$$

B. Particles Swarm Optimization

In this research work, Particle-swarm Intelligence is been implemented to reduce the total service time of spectrum handover, by varying the swarm size of the particle. Particle-swarm-optimization is a computation method, introduced by Dr. James Kennedy and Dr. Russ Eberhart in 1995. PSO is a population-based algorithm, which is been inspired by the stimulation of social behavior of fish-schooling and bird-flocking. A particle is the key element of PSO that can be an insect or a fish or a bird. A swarm is the collection of N moving particles that communicate with each other using search directions. Ever particle is initialized with a random position and velocity. During each iteration, particles update their positions on basis of pervious experiences gained. For each particle there is a local-best (pbest) and a global-best (gbest). The pbest keeps record of the location of the best solution found so far by the particle. The overall best value of position traced by the global version of the swarm, which is termed as gbest. A fitness function is the one whose value is to be optimizes with PSO. The schema of PSO algorithm is been demonstrated in Fig. 1 [15].

The schema begins with the initialization of swarm with random positon X, velocity vector V. Now evaluate fitness of every particle and compare it with values of gbest and pbset. If value of fitness is better than gbest then we update the value of gbest by the fitness-value, whereas if, fitness-value is better than value of pbest, then pbest is updated. Now, keep updating the values of global-best and the particle-best. If the terminate is true, then give output as gbest and stop, otherwise update the value of velocity. Velocity is been updated using parameters w, c1, c2, and X_i where w is the inertial weight with regard to its velocity and c1, c2 are acceleration coefficients, and X_i is the current position. The value of new position is obtained by adding the value of current position and the value of updated velocity. After this, same procedure is been repeated for the next particle.

III. RESULTS AND ANALYSIS

In this paper, we have used MATLAB software for implementation purpose. The parameters used are shown in Table 1 and Table 2. We have varied swarm sizes and service rates of secondary user to understand their effect on the total service time of handover process.

Table 1 Control Parameters

Control Parameter	Values
Inertial weight (W)	0.9
Acceleration Coefficient, c_1	2
Acceleration Coefficients, c_2	2
Processing time, t_p	0
Channel switching time, t_s	0

Table 2 Initial Parameters

Initial parameters	Values
Swarm Size	5,15,45,95
Number of iterations	50
Number of runs	20

Total service time of the proposed algorithm with respect to arrival rate of primary user is been illustrated in Fig. 2. In this experiment setup, the swarm size is varied in order to understand its effect on the value total service time. The swarm sizes used for simulation are 5,15,45,95. The experimental result shows that the overall total service time will decrease if the value of swarm size is increased.

In Fig. 3, service rate of secondary user (μ_s) is varied to evaluate its effect on total service time. The experimental results show that when the value of μ_s is small, the disrupted secondary user would prefer to stay on the same operating channel as it would face a longer waiting-time if it tried to shift to another free channel. On the other hand, if the value of μ_s is large, then interrupted user will prefer to change its current frequency of operation because of its shorter service time.

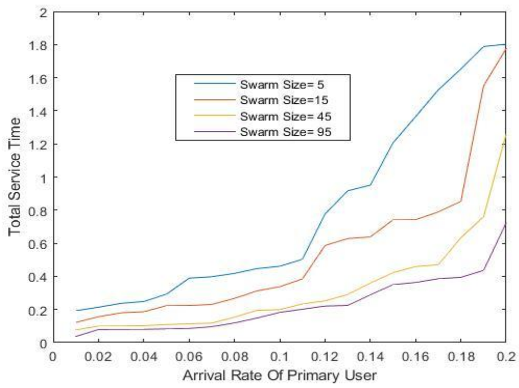

Fig. 2 Variation of Arrival Rate of Primary User *with* the Total service time at different swarm sizes

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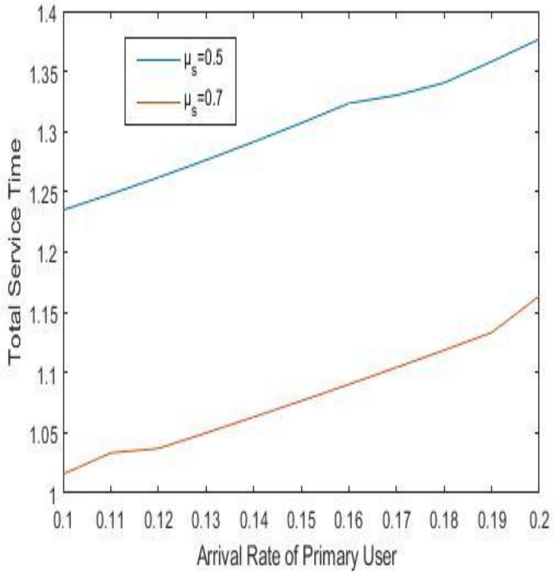

Fig. 3 Effect of Arrival Rate of Primary User with the Total Service Time at different service rates of secondary user

IV. CONCLUSION

Cognitive-radio technology makes the best utilization of the wireless bandwidth available in the network. This paper discusses various stages of cognitive-radio: spectrum sensing, spectrum decision, and spectrum sharing and spectrum mobility. The main emphasis of this research work is on spectrum mobility stage. In spectrum-mobility, secondary-users perform spectrum handover for doing spectrum transition. During this transition process, the secondary user experiences some delay due to various factors like handover preparation time, channel switching time and channel sensing time. The key performance parameter in the process of spectrum handover is handover latency. Therefore, in order to make handover process productive, the value of handover latency should be small. On the other hand, if the value of handover latency is large, then total service time will increase. This will lead to poor spectrum handover. In this research work, M/G/1 queuing model and particle swarm optimization algorithm are been implemented. M/G/1 queuing model estimates the spectrum utilization in terms of traffic arrival rate, service time and transmission latency. The concept of Particle Swarm Intelligence is used for decreasing handover latency. This is been done to reduce the total service time of spectrum handover process. Parameters used for this purpose are swarm size, number of iterations, number of runs, arrival rate and service rate.

During simulation, total service time of spectrum handover is calculated on different values of swarm sizes. It is been observed that the value of total service time decreases when the swarm size is increased. Further, the effect of service rate of secondary user on total service time is estimated. It is assessed that the unlicensed user would prefer to stay on the same channel if service rate of secondary user is small. For larger values, it will prefer to change its current frequency of operation.

The future research work shall be directed towards the application of other bio-inspired algorithms and their variants.

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