



Optimized Channel Utilization for Mobile Wireless Networks Using Artificial Searching Swarm Algorithm

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ABSTRACT

Over the years, mobile cellular communication has gained an enormous technological development. The demand for bandwidth and multiple accesses to the transmission medium has increased due to new requirements from multimedia services and the expansion of the number of users. Thus, research efforts have been made to improve the efficiency of the channel reuse allocation which is widely employed as a key strategy to manage the limited frequency spectrum allocated to a mobile cellular communication users. Therefore, this research has presented the development of an optimized wireless channel utilization in mobile cellular communication network using the artificial searching swarm optimization algorithm. The artificial searching swarm algorithm is an optimization algorithm that was inspired by the collective behaviours of biological organisms. A total of 40 cellular channels were employed for the development of the mobile cellular environment which was implemented in the MATLAB R2020a simulation platform. Calls blocking probability and probability of handoff call were employed as performance metrics. Simulation results were evaluated under different populations (10, 20 and 40 individuals) of searching swarm. Results show that the proposed model can minimize the calls blocking probability and probability of handoff calls efficiently. The call blocking probability of less than 30% was obtained when the population of the searching swarm was 40 individuals. A similar result was obtained for blocking the probability of handoff calls. These results indicate the validity of the proposed approach.

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INTRODUCTION

Wireless communications over the years has become one of the fastest industrial segment encompassing a significant number of applications. These applications include cellular networks, sensor networks, ubiquitous and pervasive computing etc. (Han et al 2012). The common challenge with all these applications involves unavailability of an efficient communication channels that satisfy the channel requirements for all users of a specific purpose (Rappaport et al 2019). This is due to the requirements from multimedia services and an increase in bandwidth as a result of huge expansion of the number of channel users. Thus, resulting in call blocking in the case of cellular communication which occurs when a base station has no free channel to allocate to a mobile user.

The two forms of blocking identified are (Adediran et al 2017):

- I. New call blocking: This refers to the blocking a new incoming call to the user
 - II. Handoff blocking: This refers to the blocking of ongoing calls due to the mobility of the users.
- With the rapid development of mobile communication technology, the distribution of cell becomes close under the limited spectrum capacity. In order to meet the growing user demand with available frequency spectrum, communication channels need to be allocated effectively and efficiently otherwise the performance of the communication system may degrade significantly.

Researchers have made a significant effort towards improving the efficiency of channel

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reuse, which is widely employed as the key strategy to manage the limited electromagnetic spectrum allocated to mobile cellular communication systems. A channel reuse technique which considers that any geographic coverage area is divided into cells in such a way that identical channels can be simultaneously assigned to calls in distinct cells have been presented by researchers to address some of this challenge. However, a channel reuse scheme might generate interferences which degrade the quality of transmission (Zhu et al 2017). Such interferences are divided into the cochannel and the adjacent channel types. Cochannel interference occurs due to simultaneous use of the same channel in neighboring cells, whereas adjacent channel interference is caused by simultaneous use of adjacent channels in the same cell (cosite) or in neighboring cells (adjacent channel) (Fan et al 2016). In order to effectively utilize the wireless resources and improve the system capacity and Quality of Service (QoS), a handoff strategy design that is suitable for voice, data and multi-service has been given a significant research attention (Hamad et al, 2011; Sharna et al, 2011 and Yuan-yuan et al, 2010).

The blocking probability is a measure of the number of blocked calls experienced in the mobile network and these block calls arise from lack of network capacity to accommodate all the calls at a particular time. This is determined from the number of available channels and offered traffic load in erlang while the dropping probability is the probability that calls that originally granted access to the network channels, but due to certain factors such as electromagnetic causes and irregular user behavior are terminated during conversation. The evaluation of drop calls is referred to as handover blocking probability and the handover rate is an estimate of the handover traffic arrival rate, which is an input parameter in the determination of network call blocking probability. Blocking probability of new call requests and dropping probability of handoff call requests are criteria mostly employed to evaluate the performance of mobile cellular communication systems. In such systems, high percentages of handoff failure severely affect the overall system performance; thus, the efficiency of channel reuse is improved by using proper procedures to give priority to handoff calls (Kim et al., 2016). Hence, a channel can be simultaneously used by a number of cells, attaining desired standards of

quality of service, if a particular traffic demand and some spectrum compatibility (EMC) constraints are satisfied. In order to estimate the volume of offered traffic load in erlang placed on mobile communication network and to optimize its capacity and the proportional number of block calls in the system, researchers have proposed several heuristics and met-heuristics optimization approach for solving the channel allocation problems (Abid et al 2018).

These metaheuristics algorithms which are bioinspired were based on the collective group behaviors of animals such, flocks of birds, school of fish, swarm of bees, foraging behaviors of bacterial *E. coli*, light attraction of fire fly etc. These consequently resulted in the development of an optimization algorithms like Artificial Fish Swarm Algorithm-AFSA (Lei. et al., 2002), Particle Swarm Optimization-PSO (Eberhart & Kennedy, 1995), Artificial Bee Colony-ABC (Karaboga, 2005) Bacterial Foraging Algorithm-BFA (Passino, 2002), Dove Swarm Optimization Algorithm-DSO (Mills et al., 2010), Fire Fly Algorithm (Yang, 2010), Artificial Searching Swarm Algorithm-ASSA etc.

The mobile wireless channel utilization problem can be viewed as a large-scale dynamic optimization task to be carried out in dynamic and stochastic environments, considering multiple goals and constraints. This kind of problems are mostly solved efficiently using any of the suitable algorithm listed above. Thus, in this research, an optimization algorithm which is inspired by the Swarm of bionic intelligence system (ASSA) is employed for optimizing the wireless channel utilization in cellular system. The ASSA was recently proposed in 2009 by chen (Chen et al., 2009). Instead of relying on a known operator (teacher), the design presented in this research learn an optimized assignment policy by directly interacting with the mobile communication environment.

MATERIALS AND METHODS

In this chapter, the design methodology employed for the successful completion of the research are detailed.

Representation of Cellular Environment Model

The coverage area of a cellular environment is divided into cells of hexagonal shape where a reference cell k is in a compact

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pattern with its surrounding cells. The design in this dissertation allow to uses any available channel if the channel satisfies the spectrum constrains. Consider a cellular system with N number of cells and D number of channels. Each channel state (which could be *ON-0* or *OFF-1*) is represented by the artificial searching swarm. The M artificial searching swarm represent the

state of a particular cell. An individual in the artificial searching swarm represents a potential channel assignment depending on their fitness. Assuming a cellular system consisting of N number of cells and D dimension of channels. Individuals in the cellular system is donated by a swarm of artificial searching swarm as follows

$$P_{(N,D)} = N \times D$$

where

$P_{(N,D)}$ represent the coordinate of a particular cell. Which is represent using equation 3.1 in the *ON* or *OFF* state.

$$P_{(i,j)} = \begin{cases} 1 & \text{if channel } j \text{ is in use in cell } i \\ 0 & \text{otherwise} \end{cases}$$

The artificial searching swarm representation channel allocation solution is given as follows

$$C = \begin{bmatrix} c_{1,1} & c_{1,2} & \dots & c_{1,D} \\ c_{2,1} & c_{2,2} & \dots & c_{2,D} \\ \vdots & \vdots & \vdots & \vdots \\ c_{N,1} & c_{N,2} & \dots & c_{N,D} \end{bmatrix} \quad 3.3$$

Each element in equation 3.3 is a representation of one individual channel allocation which is a swarm of bionic agents.

Objective Function Formulation

The objective function is used to evaluate the fitness of an individual's adaptability to the cellular environment. In this research, each

individual in searching swarm represents an option of a channel assignment for all cells. The fitness formulation is focused on evaluating each channel assignment for a requested call, considering the present state of the system in terms of new calls, handoff calls and spectrum constrains. The fitness function is formulated as follows:

$$F_i = \sum_{j=1}^{N,D} fit(i,j) + \sum_{i=1}^N P_i \quad 3.4$$

The fitness $fit(i, j)$ is given by the following equation

$$fit(i, j) = n_1(j)r_1 + n_2(j)r_2 + n_3(j)r_3 + n_4(j)r_4 \quad 3.5$$

Where

$fit(i, j)$ is the fitness of a cell i for each channel j ;

$n_1(j)$ is the number of cochannel cells around cell i in which channel j is in use;

$n_2(j)$ is the number of cochannel cells around cell i in which channel j is not in use;

$n_3(j)$ is the number of other cochannel cells around cell i using channel j ;

$n_4(j)$ is the number of channel to be blocked due to constraints of assigning channel j

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$n_5(j)$ is the number of dropped handoff calls referring to cell i ;

and r_1, r_2, r_3, r_4, r_5 are integer coefficient which are randomly determined in the following order $r_1 > r_2 > r_3 > r_4 > r_5$. The value of r_1 and r_2 must be positive in order to ensure better assignment, and the values of r_3, r_4 and r_5 should be negative in order to reduce unsuitable assignment.

Channel Constrains

The problem of channel utilization usually involves three constraints. These three constraints which are considered in this research are discussed in the following subsection

Cochannel constraint (CCC)

The first constraint is the cochannel constraint which state that the cells satisfying the minimum acceptable carrier to interference ratio are the cochannel cells. And the corresponding minimum distance between the cochannel cells is the cochannel reuse distance

Adjacent channel constraint (ACC)

The second constraint is the adjacent channels constraint. This state that adjacent channels cannot be simultaneously assigned to adjacent cells. Thus, channels assigned to adjacent cells must keep a minimum distance of channels apart and this distance should be larger than that of cochannel constraint.

Cosite constraint (CSC)

The third constraint is the cosite channels constraint which state that any pair of channels in the same cell must keep a minimum distance of channels apart. The distance of cosite channel constraint should be larger than that of adjacent channel constraint.

Artificial Searching Swarm Algorithm Utilization

The searching swarm implementation is similar to all other swarm intelligent optimization algorithm such artificial fish swarm, particle swarm and Artificial bee colony algorithms. Assuming the problem under consideration has D - dimensional search space and the searching swam has a population of N , then, initialize the search swarm X such that:

$$X = [x_1, x_2, \dots, x_{ND}] \quad 36$$

Where;

X is the initial position of the swarm;

D is the dimension of the search space (problem under consideration);

N is the total population of the searching swarm.

The fitness of the initialized random positions in equation 3.6 is evaluated as follows

$$Y = f(X) \quad 37$$

The procedural flow for the implementation of the searching swarm algorithm are detailed as follows:

- a.) Initialization
 - i.) Set the parameters (population of swarm, Problem dimension and Iteration)
 - ii.) Initialize the searching swarm randomly
 - iii.) Evaluate the fitness value
- b.) Start iteration counter and increase by 1 consecutively. Evaluate individual searching swarm in turn as follows:
 - iii.)
 - i.) If the searching swarm receive a call from its companion, then move forward a step toward the caller's position.
 - ii.) Else, implement reconnaissance (i.e. evaluate its own fitness). If a better goal (fitness) if found, copy the location and send a call to other member of the searching swarm. This movement is archived using the following mathematical equations

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$$X = X_i + r_1 \times |X_s - X_i| + w_1 \times r_2 \times |X_g - X_i| \quad 3.8$$

$$X_{i+1} = X + w_2 \times \frac{X - X_i}{\|X - X_i\|} \quad 3.9$$

Where;

$w_1 \geq 1$ is an inertial weight introduce to enhance the search abilities and accelerate the convergence rate of the artificial searching swarm.

w_2 is a random number generator in the step direction. i.e. $w_2 = rand(0,1) \times step$

X_i is the current position of the searching swarm;

X_s is the previous position of the searching swarm;

X_g is the current best position of the searching swarming;

r_1 and r_2 are random number generated at different interval.

- iv.) Else move by a step randomly.
- c.) Evaluate the current fitness value, compare with the best fitness of the

swarm and individual fitness and store the best fitness in the score board.

- d.) Terminate if the stopping criterion has been met (i.e. maximum iteration reached) else return to step c.)

The three rules (communication reconnaissance and move) of the artificial searching swarm algorithm compel the algorithm to move towards the best solution. For example; the communication rule compels the searching swarm to move towards the better goal and accelerate the convergence rate of the algorithm. The reconnaissance rule compels the algorithm to move away from the local solution and enhance movement towards the global solution. The move rule ensure that the algorithm never terminate until a suitable solution and stopping criteria is met. The flow chart for the implementation of the propose mode is given in Figure 3.1.

The cellular environment showing the distribution of fourthy (40) hexagonal shaped cells generated using MATLAB is given in Figure 1

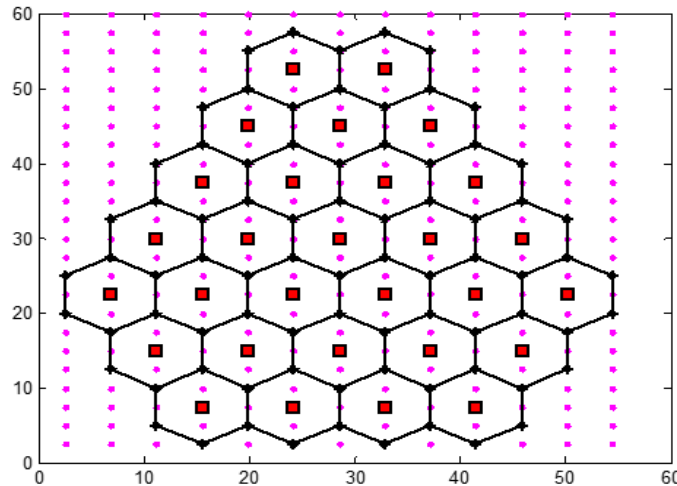


Figure 1: MATLAB generated Cellular Environment

RESULT AND DISCUSSION

In order to evaluate the performance of the proposed model, the relationship between the

number of generated calls and number of block were evaluated as shown in Figure 2

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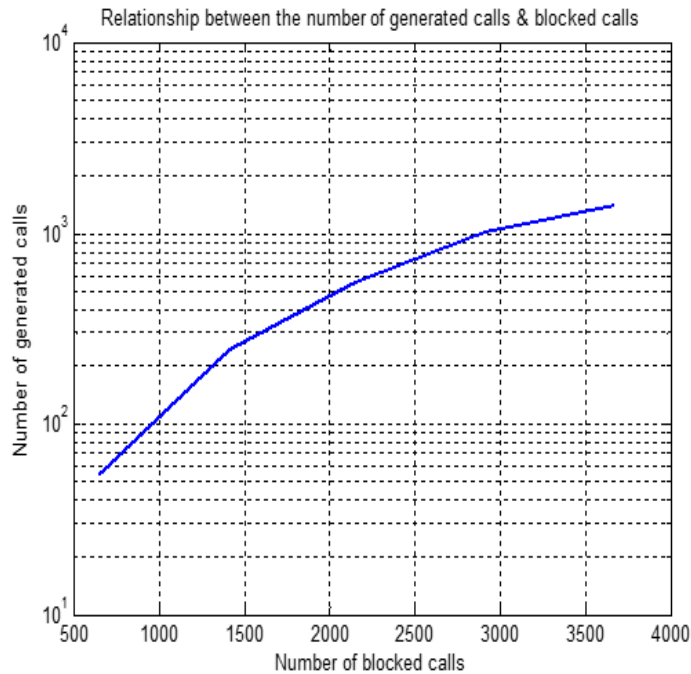


Figure 2: Relationship between Number of Generated Call and Block Calls

From Figure 2, it can be observed that, as the number of generated calls increase the number of block calls also increases. It can be observed that only about 1,400 out of the 10000 generated calls were blocked. This is an indication of over 85% efficiency of the developed

model. In order to further estimate the performance of the proposed technique, the relationship between the call blocking probability and the number of generated calls is generated as shown in Figure 3.

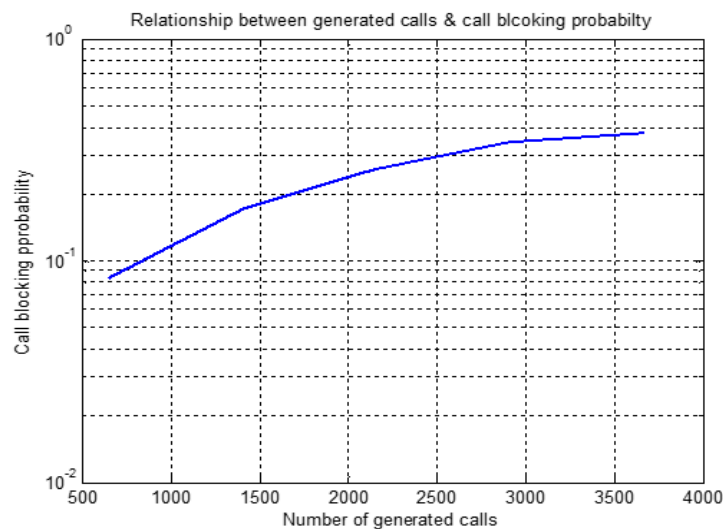


Figure 3: Relationship between Call Blocking Probability and Number of Generated Call

From Figure 3, it can be observed call blocking probability increases as number of generated call increase. However, the proposed technique was able to attain a call probability of less than 0.4 as can be observed from Figure 3.

Blocking Probability of New Calls

The performance of the model using blocking probability of new call was evaluated

under different population of the artificial searching swarm algorithm. This is with the hope determining the right variability of population that give the best call blocking probability. Figure 4 shows the blocking probability of new calls when the searching swarms population is varied between 10, 20 and 40 individuals.

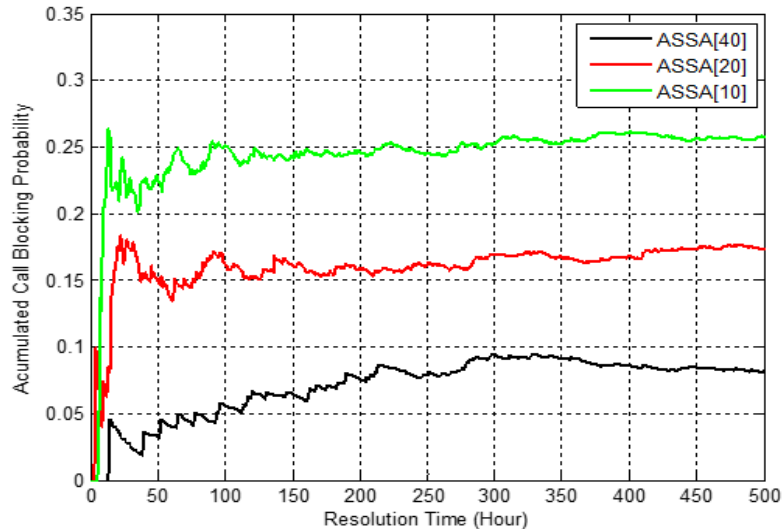


Figure 4: Blocking Probability of New Calls

From Figure 4, Preliminary simulation for the ASSA schemes within the selected population range evaluated the blocking probability of new calls as a function of time for three different populations. It can be observed that, the option with a population of 40 individuals provides the best (lowest) blocking probability all through the simulation. Perhaps, there is tendency of an option with marginal performance for searching swarm population high than this values. There is no guarantee for the best choice of individuals, however, the selected population

provide a good alternative to fulfil the objectives of this research.

Dropping Probability of Handoff Calls

The performance of the proposed model using the dropping probability of handoff calls under different population of individuals was evaluated. The same populations described in the previous subsection were selected in order to ensure uniformity under the same variability of populations. The simulation result is presented in Figure 5.

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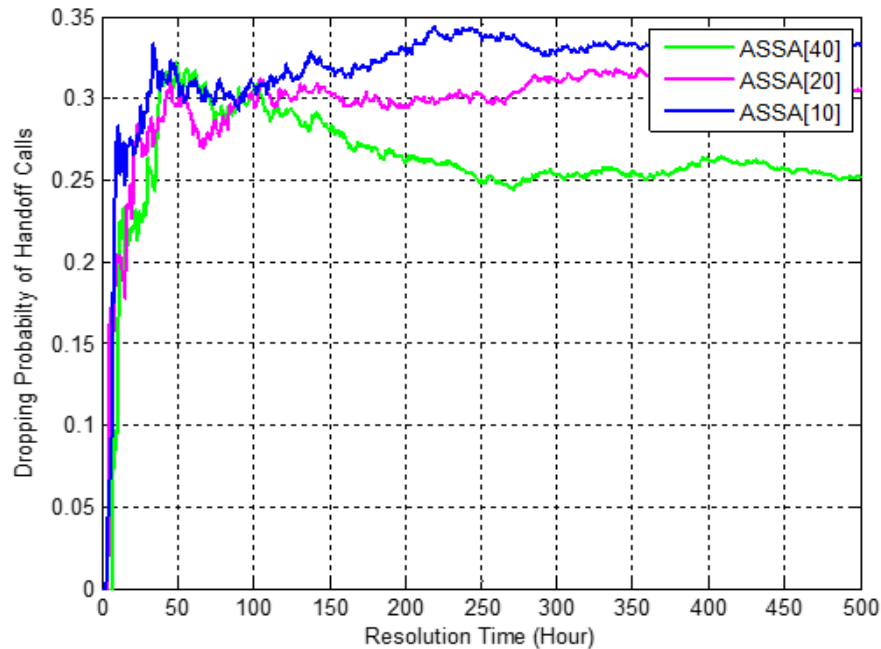


Figure 5: Dropping Probability of Handoff Calls

Considering the dropping probability of handoff calls, Figure 5, it can be observed that all the variable populations of ASSA considered provide a reasonable result. Although, the response with 40 populations of individuals searching swarm appears to better, but on the basis of overall best (lowest) handoff blocking probability, the response with 20 populations of searching swarm performs better.

In general, low blocking probability of new calls is achieved with a slight increase in the dropping probability of handoff calls using the approach proposed in this research, because, fewer resources are available to assigned to the handoff call.

CONCLUSION

This research has developed an optimized wireless channel utilization in mobile cellular network using artificial searching swarm optimization algorithm. The model was developed in MATLAB R2014a simulation environment and the following finding were recorded:

- The number of block calls increases as the number of generated calls also increases.
- The call blocking probability also increase as the call resolution time is increase. However,

the proposed model is capable of reducing the call blocking to as less than 30% with varying population of artificial searching swarm

- With varying population of artificial searching swarm, result indicates that, the best blocking probability is achieved when the population 40 searching swarm was used, compared to when 20 and 10 searching swarm was used.
- Also, for the hand off call probability, results indicate that, the lowest handoff call probability is attained when the population of searching swarm is 20 individuals, but however, the overall best handoff call probability is obtained for 40 searching individuals.

RECOMMENDATION

Over the years, Dynamic Channel Allocation has been a major concern for both academic and industrial researchers in the area of mobile cellular communication. Due to the environment behavior and the traffic load demand in cellular communication, an optimized channel assignment involved the dynamic determination of the way to distribute the channels among the cells in order to minimize the

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blocking probability of new calls and the dropping probability of handoff calls while simultaneously satisfying the spectrum constraints. Thus, this research work developed an optimized channel utilization in mobile cellular communication using the artificial searching swarm optimization algorithm. The proposed model was implemented in MATLAB R2014a simulation environment. Results indicate that the proposed artificial searching swarm optimization based dynamic channel assignment can attain a blocking probability of less than 30% when the population of the searching swarm is 40 individuals. Also, the relationship between the dropping probability of handoff calls indicates that less than 30% can be obtained when the population of searching swarm is 40 and 20 individuals. This results indicates. In summary these results indicate that the proposed model is scalable of dynamically allocating wireless channel in mobile cellular network.

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