An Efficient Dynamic Orthogonal Variable Spreading Factor Code Allocation Approach in WCDMA through Swarm Intelligence Technique

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***Abstract*— CDMA is the access technique adopted in the third generation wireless system. In this technique, all users share the same bandwidth simultaneously but with different codes. This sharing generates interferences that can reduce the overall throughput of the WCDMA network when using a weak code allocation algorithm. On the other hand, shared channels are made for the transmission of bursty data as they allow a single OVSF channelization code to be shared among several users. In WCDMA, effective utilization of OVSF codes has become an active area of research as the number of codes is very limited. It is a fact that the successor and predecessor codes of OVSF cannot be used simultaneously when a specific code is used in OVSF as their encoded sequences become indistinguishable. Consequently, OVSF code tree has inadequate number of available codes. Thus, this research work uses a Swarm Intelligence Technique called Artificial Bee Colony (ABC) approach for dynamic OVSF code assignment in WCDMA networks. The simulation results show that the ABC especially with diploid structure provides reduced code blocking probability and improved spectral efficiency in the system when compared to the CCA and DCA schemes.**

Keyword- Call Admission Control (CAC), Code-Division Multiple Access (CDMA), Dynamic Code Assignment, Artificial Bee Colony

I. INTRODUCTION

Two important issues under research in WCDMA systems are spreading codes are studied in [1, 2] and modulation in [2]. Spreading is the fundamental operation of WCDMA radio interface. The spreading codes in WCDMA are of two types namely channelization code and scrambling code. The channelization codes in WCDMA are OVSF codes. The channels in the forward link and reverse link use theses codes for transmission. OVSF codes are shorter in length and are made from orthogonal function. The orthogonality property of OVSF codes makes it suitable for WCDMA. The signals from two or more UEs in the reverse link are transmitted to same BS in the cell from separate locations. This change in distance gives rise to change in time for the signals to reach at the BS. The orthogonal property of the OVSF codes is disturbed due to different arrival times. Hence the OVSF codes are not used for calls separation in the reverse link. The facility to handle variable call rate is also incorporated in OVSF codes. In contrast to OVSF codes, scrambling codes are quite long (with the exception of the reverse link of the short scrambling code).

Scrambling codes are generated from the stream called pseudo noise (PN) sequences is studied in [3]. A previous study is studied in [4] proposed an optimal dynamic code assignment scheme to reduce the code blocking. Conceptually, if OVSF-CDMA can dynamically reassign codes to connections on the fly, available codes can be aggregated and reserved for forthcoming calls with acquiring higher transmission rates. Such an approach, however, introduced un-neglected overheads without partitioning the codes initially and assigned identical priorities to traffics without taking the QoS specifications into consideration. In [5] Aimed at optimizing system utilization for three traffic classes including voice, video and low priority data by preempting codes allocated to ongoing connections. Codes allocations were according to the pre-established rules, i.e., particular codes in the system were reserved for voice and video traffics. Re- serving particular codes providing higher transmission rates can reduce the call blocking rates for those calls acquiring higher data rates. This approach, however, cannot dynamically aggregate the codes released and the utilization of codes cannot be fully exploited. The CDMA systems using OVSF codes suffer from code blocking. A number of assignment and reassignment schemes are proposed to reduce the effect of code blocking is studied in [6], [7], [8], [9], [10], [11].

In uplink all the users can be differentiated by unique scrambling code. In downlink, all calls propagate through same base station and hence efficient use of OVSF codes becomes significant. This research work focuses on providing significant results for the OVSF code assignment using a Meta heuristic algorithm. This paper presents an efficient Artificial Bee Colony (ABC) technique for the purpose of OVSF code assignment, which could adjust the parameters adaptively based on the value of individual fitness and dispersion degree of population.

II. RELATED WORK

In WCDMA all users share the same carrier under the direct sequence CDMA (DSCDMA) principle. In the 3GPP specifications orthogonal variable spreading factor (OVSF) codes are used as channelization codes for data spreading on both downlink and uplink. OVSF codes also determine the data rates allocated to calls. WCDMA supports data rates up to 2.048 Mbps in 5 MHz bandwidth using variable spreading factors is studied in [12]. When a particular code is used in OVSF, its descendant and ancestor codes cannot be used simultaneously because their encoded sequences become indistinguishable is in [8]. Therefore, the OVSF code tree has a limited number of available codes. Because one OVSF code tree, along with one scrambling code, is used for transmissions from a single source that may be a base station or mobile station, the same OVSF code tree is used for the downlink transmissions and therefore the base station must carefully assign the OVSF codes to the downlink transmissions studied in [9].

OVSF (Orthogonal Variable Spreading Factor) codes are used in WCDMA uplink and downlink transmission for multirate traffic. The orthogonal property of these codes leads to code blocking and new call blocking. Two code (or slot) sharing assignment schemes are proposed to reduce the effect of code blocking using OVSF and NOVSF (non blocking OVSF) codes. The schemes favor the real time calls as they are given higher priority in all 3G and beyond networks. The benefit of the proposed scheme is the better handling of non quantized rates compared to other novel single code and multi code assignment schemes. Both single code and multi code options are analyzed for OVSF as well as NOVSF codes. Simulation results are discussed to show the benefits of the proposed scheme in [13].

Efficient resource allocation for multi-class traffic with QoS guarantee is an important issue in integrated multimedia mobile communication networks. In the third generation mobile communication systems, the Orthogonal Variable Spreading Factor (OVSF) codes are used as spreading codes. The use of OVSF codes allows the spreading factors to be changed for variable bit-rate requirements. In this paper, we presented the code- based guard channel schemes and analytical models for QoS management in W-CDMA systems. Compared with traditional channel-based schemes, the proposed schemes and analytical models exactly reflect the restrictions of OVSF code tree characteristics and are suitable for W-CDMA systems. From the illustrations and numerical results, we find that the proposed model is easy to construct and to analyze QoS management schemes in W-CDMA systems. It can also be extended to more complicated multi-class traffic types systems in [14].

Orthogonal variable spreading factor (OVSF) codes provide variable data rate transmissions for different bandwidth requirements in 3G WCDMA networks. In order to effectively utilize limited OVSF resources, many works in the literature have focused on dynamic code assignment (DCA) schemes. This paper investigates genetic algorithm (GA) based approach for dynamic OVSF code assignment in WCDMA networks. Different from existing conventional code assignment (CCA) and dynamic code assignment schemes, population is adaptively constructed according to existing traffic density in the OVSF code-tree. In order to improve the ability of the GA, we employ so-called ‘‘dominance & diploidy’’ structure to adapt to changing traffic conditions. Performances of these two methods are evaluated in terms of blocking probability and spectral efficiency, and also compared with CCA and DCA. The simulation results show that the GA, especially with diploid structure, provides reduced code blocking probability and improved spectral efficiency in the system when compared to the CCA and DCA schemes. In addition to these, different GA operators are also tested under varying traffic loads to increase the overall system performance in [15].

III. OVSF CODE TREE

Hadamard-Walsh matrix is utilized to construct a successive orthogonal variable codes which can be denoted by the tree as shown in Figure 1.

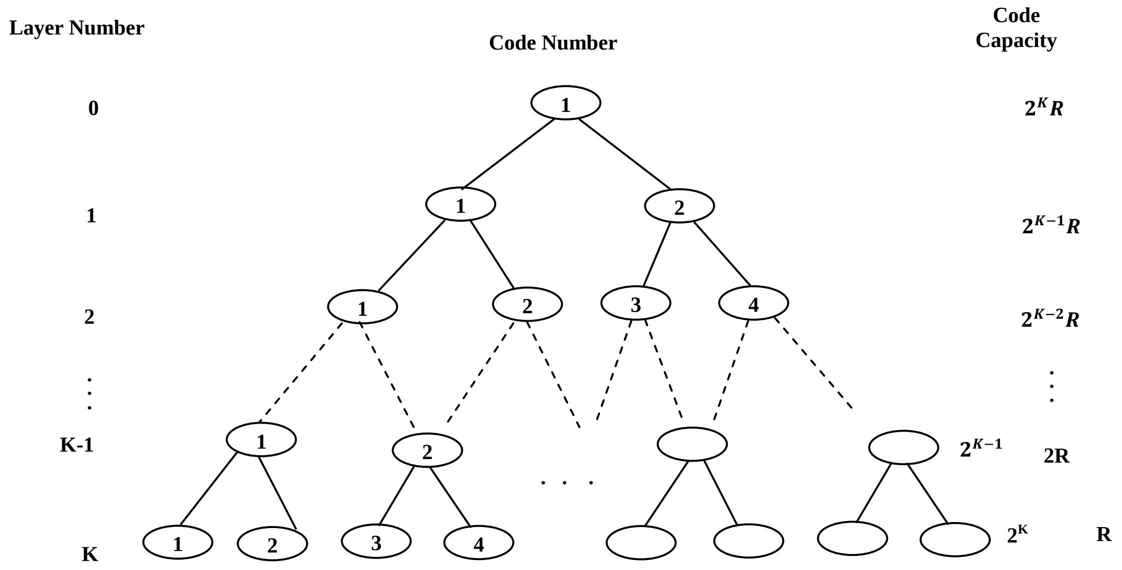

Fig 1. OVSF code tree

A K layer code tree [12] is shown in the figure 2. The OVSF code tree is called as a binary tree with K layer, where the each and every node represents a channelization code (k, m), where$k = 0,1, \ldots, K$, $m = 1, \ldots, 2^K$. The lowest layer is the leaf layer and the highest layer is called as root layer. The data rate that a code can be support is called its capacity. Consider the capacity of the leaf codes (in layer K) be denoted as R. Then the capacities of the codes in the respective layer $(k-1), (k-2), \ldots, 1, 0$ are $2R, 4R, \ldots, 2^{K-1}R, 2^K R$ respectively, as shown in Fig 1. In OVSF Code tree Layer k has 2^k codes and they are consecutively labeled from left to right path, starting from one. The m^{th} code in layer k is denoted to code (k, m). In each layer the total capacity of all the codes is $2^k R$, it is irrelevant of the layer number. Also define the maximum spreading factor $N_{max} = 2^k$ as the total number of codes in layer K.The maximum capacity of the system is expressed as $capacity = 2^K R$ where K denotes the highest layer of the tree and R represents the fundamental data rate.

After a process period, available codes will be spread out around the code tree. This random spread out of the available codes within the code tree is called fragmentation which in turn results in code blocking. This would greatly affect the performance of the system.

IV. CODE BLOCKING SCENARIO

Code blocking is the major limitation of OVSF-CDMA system. In figure 2, code tree with four layers is taken into consideration. The maximum capacity of the code tree is 8R. in the code tree, two codes with SF4 (for data rate 2R) and 8 (for data rate R) are occupied. Hence, the capacity used for the OVSF code is 3R. The remaining capacity of the code tree is 8R-3R=5R. If a new call with data rate 4R arrives, code from the third layer is needed. The code tree is not capable to offer code for the new call, as both the codes equivalent to 4R capacity is blocked. Thus, this is a scenario in which a new call cannot be supported even if the system has adequate capacity to deal with. This scenario called code blocking has to be avoided through efficient and optimized assignment and reassignment schemes [17].

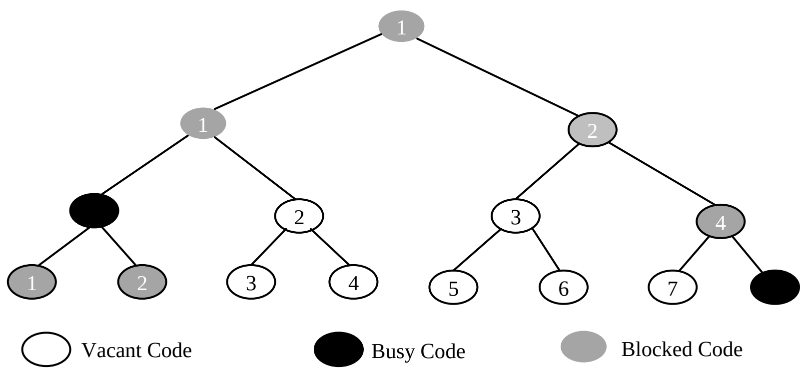

Fig 2. Code Blocking Scenario

V. HEURISTIC APPROACHES IN OVSF CODE ALLOCATION

In order to determine appropriate OVSF code to the call requested user due to the code blocking problem, reallocation of assigned OVSF codes in the code tree helps to identify this possible code. Genetic algorithm is a heuristic approach which is observed to provide significant results in optimization problems [18].This section discusses this reallocation process starting based on heuristic algorithms to make OVSF code assignment strategy. Execution is not essential for resource assignment in idle state. Call is started with the call processor's signaling to resource manager to assign resources for a traffic channel. Initially, availability of capacity is enquired in the code tree in order to make a decision whether to support the requested call rate in the system. If there is adequate capacity, then availability of requested rate OVSF code is checked among unused codes in the relevant layer, where the call can be supported [19]. If a call cannot be assigned a code due unavailability of the code with the requested rate (or all supported codes for this rate are not orthogonal to the assigned codes), GA block is executed. In the GA block, reassignment process of OVSF codes is performed [20].

VI. PROPOSED IMPROVEMENT IN ADAPTIVE GENETIC ALGORITHM

Karaboga et al., proposed an Artificial Bee Colony (ABC) algorithm in [21]. The algorithm is used to find an optimal solution to the problem. The algorithm works based on the honey bee foraging behavior. The performance of the ABC algorithm is studied in [22]. The performance of ABC algorithm on training neural networks is examined by [23] and by [24] a pattern classification beside extensively used in gradient-based and population based optimization algorithms.

<u>Pseudo-code of the ABC algorithm:</u>

Load training samples

Generate the initial population $z_i, i = 1, \ldots\ldots sN$

Evaluate the fitness (f_i) of the population

Set cycle to 1

Repeat

FOR each employed bee {

    Produce new solution v_i by using (3)

    Calculate the value of f_i

    Apply greedy selection process}

Calculate the probability value $p_i$for the solution (z_i) by (2)

FOR each Onlooker bee {

    Produce new solution v_i by using (3)

    Calculate the value of f_i

    Apply greedy selection process}

If there is an abandoned solution for scout

Then replace it with a new solution which will be randomly produced by (4)

Memorize the best solution so far

Cycle=cycle+1

Until cycle=MCN

In ABC algorithm, three bees are present employed bees, onlookers and scouts. To choose a food source a bee is waiting to take decision is called as onlooker bee and the bee which is already visited that food source is called as employee bee. A scout bee is used to find out a new source in a random manner. The position of the food source signify the finite solution to the optimization problem and the nectar amount of the food source is match with the fitness value is measured by

$$fit_i = \frac{1}{1 + f_i} \qquad (1)$$

The cost function is calculated f_i according t is studied in [29].

An artificial onlooker bee selects a food source based on the likelihood value linked with that food source, p_i computed by the following expression (2):

$$p_i = \frac{fit_i}{\sum_{n=1}^{sN} fit_n} \qquad (2)$$

where SN is the number of food sources equal to the number of employed bees, and fit_i is the fitness of the solution given in Eq. (1) which is inversely proportional to the f_i given in Eq. (1) where f_i is the cost function of the clustering problem.

In order to generate a candidate food position from the old one in memory, the ABC exploits the following expression (3):

$$v_{ij} = z_{ij} + \emptyset_{ij}\left(z_{ij} - z_{kj}\right) \qquad (3)$$

Where $k \in \{1,2,\ldots\ldots SN\}$ and $j \in \{1,2,\ldots\ldots D\}$ are randomly chosen indexes. Although k is identified randomly, it has to be different from i. ϕ_{ij} denotes a random number between [-1,1]. It controls the production of neighbor food sources around z_{ij} and represents the comparison of two food positions visually by a bee. As can be seen from (3), as the difference between the parameters of the z_{ij} and z_{kj} decreases, the perturbation on the position z_{ij} gets decreased, too. Therefore, as the search reaches the optimum solution in the search space, the step length is minimized.

The food source of the nectar is vacant by the bees is replaced with a new food source by the scouts. In ABC, this is simulated by generating a position at random and replacing it with the abandoned one. In ABC, if a position cannot be further enhanced via a preset number of cycles, then that food source is consider as abandoned. The value of preset number of cycles is an essential control parameter of the ABC algorithm, which is called ‘‘limit” for abandonment. It is to be assumed that the abandoned source is z_i and$j \in \{1,2,\ldots,D\}$, then the scout discovers a new food source to be replaced with z_i . This operation can be defined as in (4).

$$z_i^j = z_{min}^j + rand(0,1)\left(z_{max}^j - z_{min}^j\right) \qquad (4)$$

After each candidate source position v_{ij} is generated and then estimated by the artificial bee, its performance is assessed with that of its old source position. If a new food source has equal or better nectar than the old source, it is replaced with the old source in the memory. If not, the old one is retained in the memory. Alternatively, a greedy selection approach is employed as the selection process between the old and the candidate one. The global optimal solution is obtained.

VII. Proposed Dynamic OVSF Code Allocation Using Particle Swarm optimization Technique

In this paper to overcome the drawbacks of the existing methods an ABC technique is proposed to improve the code blocking probability. The flowchart of the proposed approach is given in figure 3 [15]. If a call cannot be allotted a code due to unavailability of the code with the requested rate then ABC block is executed. In the ABC block, reassignment process of OVSF codes is carried out. A sample OVSF code tree is shown in Figure 4. The OVSF code tree which is input to the ABC block is called as initial Population (P_{ini}) and this Population is denoted with the index number which belongs to active users in the given code tree (P_{ini} = [6 9 14 16 21]).

Here in this approach the integer value is taken from the index numbers 1 to SF-1, allocated from root code which is indicated as index 1. Then the left descendant code is index 2, right descendant code is index 3, this is nonstop up to the lowest layer-rightmost branch. Each active user's index number in the initial population is termed as a bees denoted by an integer number. The data bit rates of P_{ini} in are [4R 2R 2RRR] which is equivalent to the index numbers in the OVSF code tree. R represents the fundamental data rate needed for the transmission through the lowest layer codes in the code tree. The data rates are doubled as layer is getting topper in the code tree. Hence the root code needs $\mathrm{SF} \times \mathrm{R}$ rate transmission of data. The size of initial population which generated from the bees is defined according to Eq. (5) and depends on the traffic density which is

$$n = SF - \sum_{i-1}^{V} H(i) \qquad (5)$$

Where

V= total number of active users

$H(i)$= date rate of i^{th} active user, i=1…, V.

Let V, H, and SF are 5, 10 and 16, correspondingly. As a result the initial population (n) of the bees is attained as 6 (16-10). Initial population with various code tree index numbers other than the number of data bit rates of each particle is the same as initial population. The n bees consist of existing coded information of OVSF tree is attained by means of permutation and gives an optimized result for a problem.

P_{ini} gives the first population of the bees. The 1st particle is obtained from the P_{ini}. Temporary Population TP (1) which is obtained from P_{ini} with random permutation is sequentially alloted to empty OVSF code tree from 1st population to 5th population bees. It is essential to take into consideration the orthogonality principle, while assigning codes in the OVSF code tree. Index numbers are taken to compose a new particle P (1). The process of attaining P (1) is as follows: for each gene of TP(1), the equivalent gene in P(1) is chosen as the possible leftmost OVSF code that has the same rate as this gene in TP(1). For example, the initial gene numbered by 14 in TP(1) has the rate 2R. Therefore, possible leftmost gene with rate 2R is the OVSF code numbered as 8 in P(1).

$$\mathrm{Pini} = \begin{bmatrix} 6 & 9 & 14 & 16 & 21 \\ 4R & 2R & 4R & R & R \end{bmatrix} \Rightarrow \mathrm{TP}(4)$$
$$= \begin{bmatrix} 21 & 9 & 6 & 16 & 14 \\ R & 2R & 4R & R & 2R \end{bmatrix} \Rightarrow \mathrm{P}(4) = \begin{bmatrix} 5 & 9 & 13 & 16 & 24 \\ 4R & 2R & 2R & R & R \end{bmatrix}$$

$$\mathrm{Pini} = \begin{bmatrix} 6 & 9 & 14 & 16 & 21 \\ 4R & 2R & 4R & R & R \end{bmatrix} \Rightarrow \mathrm{TP}(5)$$
$$= \begin{bmatrix} 6 & 14 & 16 & 21 & 9 \\ 4R & 2R & 4R & R & 2R \end{bmatrix} \Rightarrow \mathrm{P}(5) = \begin{bmatrix} 4 & 10 & 12 & 22 & 23 \\ 4R & 2R & 2R & R & R \end{bmatrix}$$
$$\mathrm{Pini} = \begin{bmatrix} 6 & 9 & 14 & 16 & 21 \\ 4R & 2R & 4R & R & R \end{bmatrix} \Rightarrow \mathrm{TP}(6)$$
$$= \begin{bmatrix} 21 & 16 & 9 & 6 & 14 \\ R & R & 2R & 4R & 2R \end{bmatrix} \Rightarrow \mathrm{P}(6) = \begin{bmatrix} 5 & 9 & 12 & 16 & 17 \\ 4R & 2R & 2R & R & R \end{bmatrix}$$

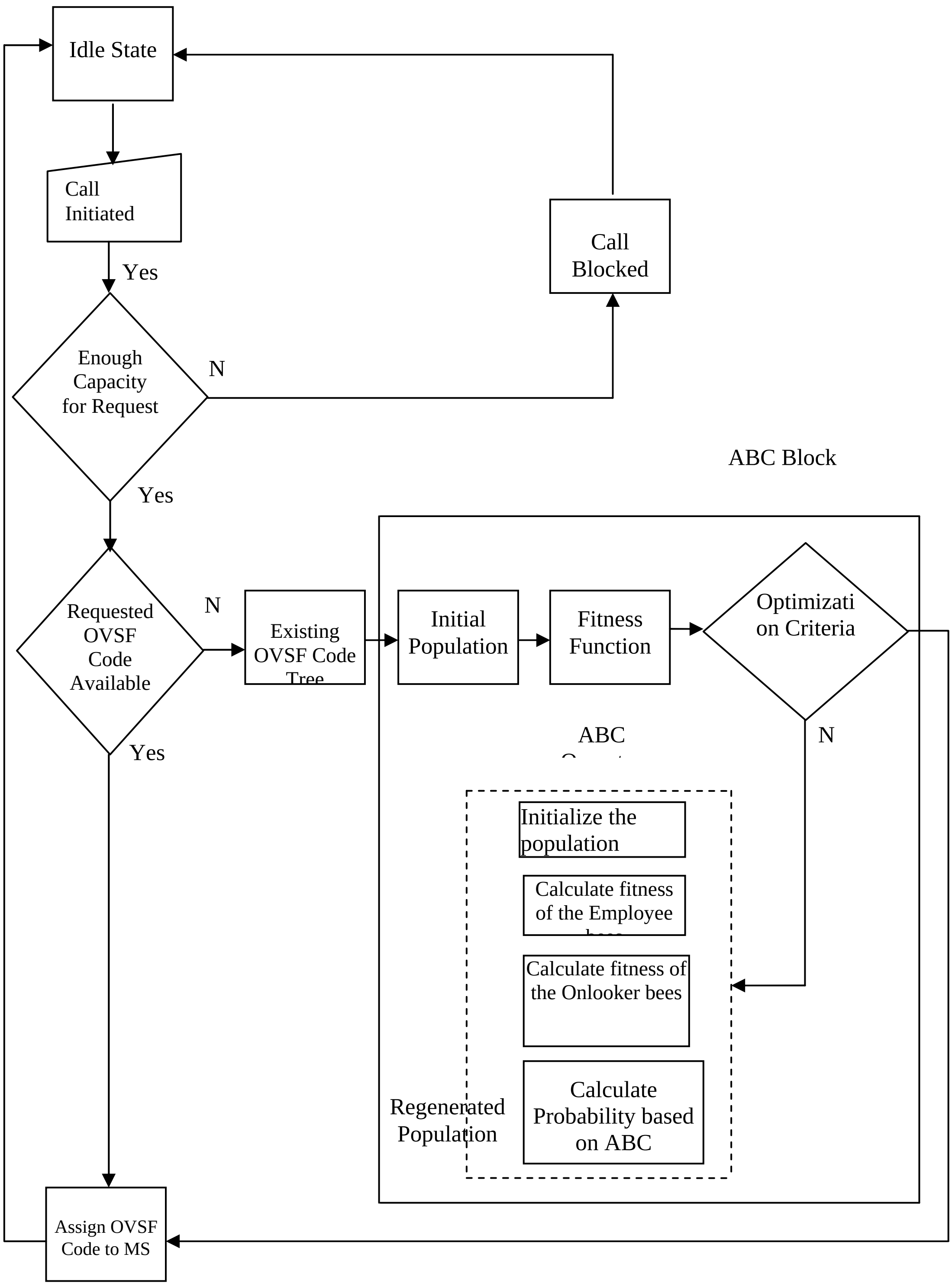

Fig 3. Flowchart of OVSF code assignment system using MAGA block

VIII. EXPERIMENTAL RESULTS AND EVALUATION

The main focus of this research is to enhance the number of free codes at OVSF code tree through reassignment of presently allotted codes. When the system still has adequate capacity to offer the data bit rate request, and requested data bit rate cannot be supported since all available codes for this data bit rate are not orthogonal to the assigned codes, reassignment of OVSF code tree assist in determining the appropriate code to the demanding user. In order to evaluate the performance of the proposed ABC based code assignment approach, it is compared with other techniques such as SGA, D&D-GA and MAGA.

IX. SIMULATED RESULTS AND EVALUATION

A. Results

Results obtained from simulations are classified into three categories, which are system performance, effects of algorithm parameters, and complexity analysis for algorithms. The performances are evaluated for the algorithms such as SGA, D&D-GA, MAGA and ABC.

B. Blocking Probability

The code blocking occurs when a new call requesting a transmission rate cannot be supported since all available codes for this rate are not orthogonal to other assigned codes, even if the code tree has adequate remaining capacity. Blocking probability is the ratio of the number of blocked calls (N_B) to total number of all incoming calls(N_T) , given by

$$\Pr(blocking) = \frac{N_B}{N_T} \qquad (6)$$

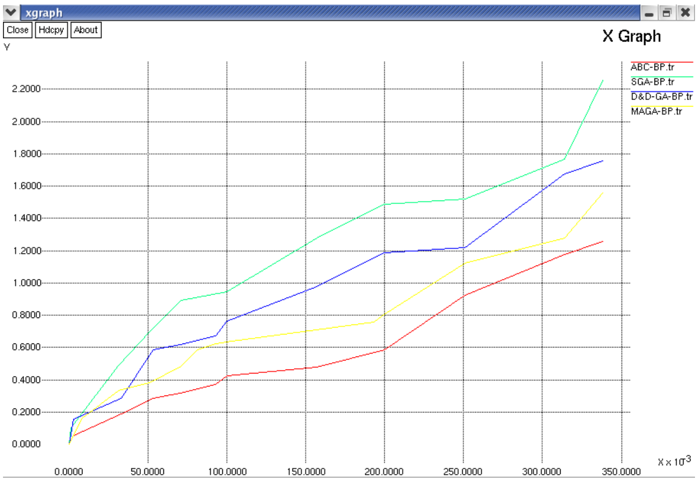

Fig 4. Blocking probability

Figure 4 shows the results of our simulations for blocking probability at different traffic loads when SF is 256. It is seen from figure that the proposed AGA performs better than D&D-GA which is followed by SGA, DCA and then CCA. For instance, AGA serves more call when it is compared with D&D-GA algorithm when traffic load is larger than 10. At higher loads, proposed algorithm performance improvement is more significant than D&DGA.

C. Spectral Efficiency

Spectral efficiency is evaluated to measure the ratio of assigned data rate (R_{assigned}) over the total requested data rate ($R_{requested}$) of all incoming calls, which is given by

$$\eta(\%) = \frac{R_{\text{assigned}}}{R_{requested}} \times 100 \qquad (7)$$

Code blocking probability focuses the number of users while spectral efficiency focuses this user' data bit rates. Figure 5 shows the spectral efficiency of the GA based methods and proposed ABC approach at different traffic loads. The spectral efficiency of the resource is inversely proportional to the traffic load in the system. It is obvious from the figure that the proposed ABC algorithm provides the significant spectral efficiency among MAGA, D&D-GA and SGA based approaches.

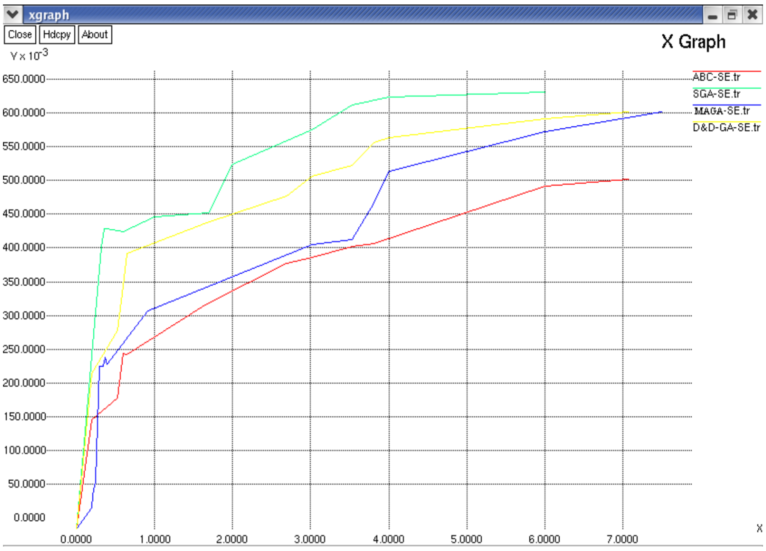

Fig 5. Spectral efficiency

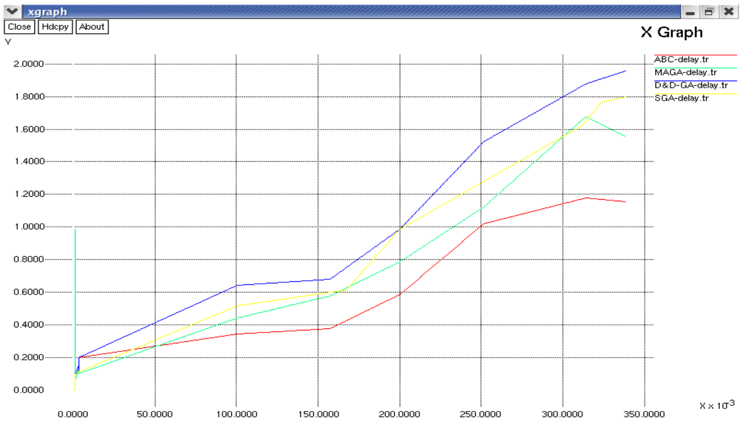

Fig 6. Delay Comparison

Figure 6 shows the delay comparison of the approaches taken for consideration. It is observed from the graph that the proposed ABC approach has lesser delay when compared with the D&D GA and SGA and MAGA approaches.

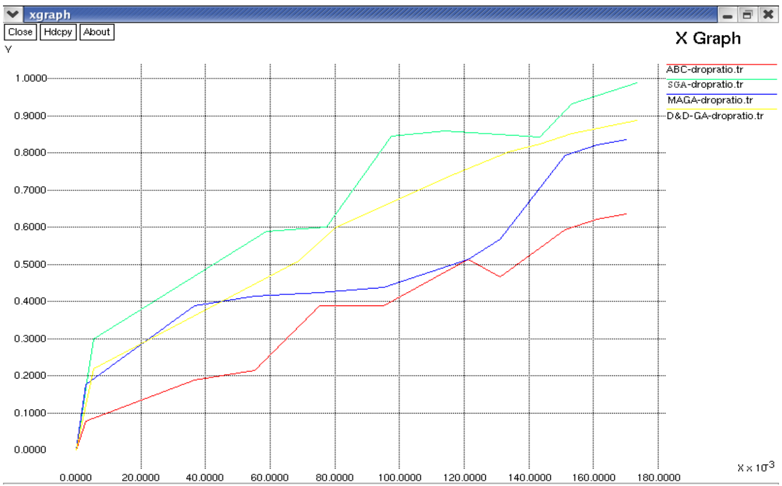

Fig 7. Drop Ratio Comparison

Figure 7 shows the comparison of the drop ratio of different techniques taken for consideration. It is observed from the figure that the drop ratio of the proposed ABC approach is lesser than the other two approaches such as SGA and D&D GA and AGA.

Through put of the proposed ABC approach is very higher when compared with SGA and D&D GA. The graph shows that maximum throughput has been obtained for the proposed approach. It is mainly due to the improvement in mutation and crossover probability.

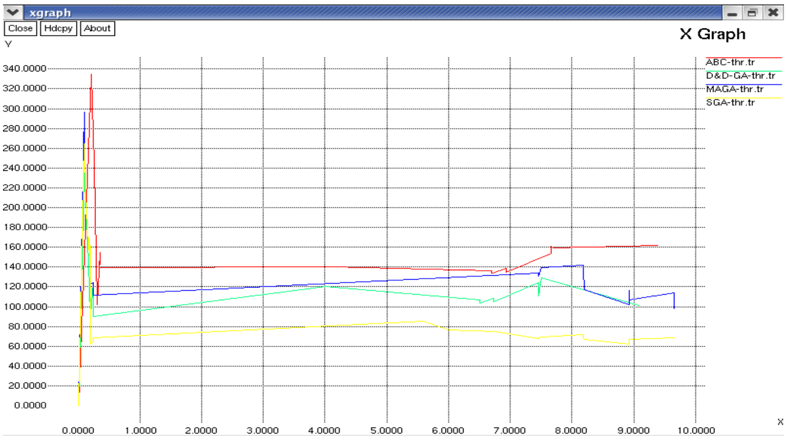

Fig 8. Throughput

X. Conclusion

The Orthogonal Variable Spreading Factor (OVSF) codes are used as spreading codes. The use of OVSF codes allows the spreading factors to be changed for variable bit-rate requirements. Real time calls are given higher priority in all 3G and beyond systems. The code blocking is the major limitation of OVSF based 3G systems which lead to call blocking in both real time and non real time calls. OVSF codes assignment have high influence on the code utilization and system performance. This research work utilizes an efficient meta heuristic algorithm called Artificial Bee Colony (ABC) based dynamic OVSF code assignment for WCDMA systems in order to reduce the call blocking and increase the spectral efficiency in the system. The simulation results show that ABC provides the smallest blocking probability and largest spectral efficiency in the system when compared to AGA, SGA and D&D-GA.

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