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Genetic Algorithm based HBCCS Technique for Optimal Resource Allocation in OFDMA-LTE System to Mitigate Interference

Kethavath Narender [1], Dr. Puttamadappa C [2]

[1]*Research Scholar, Electronics & Communication Engineering Department, Visvesvaraya Technological University, Karnataka, India.*

[2]*Professor, Electronics & Communication Engineering Department, DSU, Bengaluru, Karnataka, India.*

Abstract

LTE has become the de-facto technology for the 4G networks. It offers unprecedented data transmission and low latency for several types of applications and services. In wireless broad-band access networks, most of the indoor environments encounter serious coverage problem. In order to overcome this constraint and to improve the OFDMA-LTE performance, Genetic Algorithm (GA) and Hybrid Bee Colony and Cuckoo Search (HBCCS) techniques based Optimal Resource Allocation (RA) in OFDMA-LTE System introduced. The optimal power values are updated to allocate all the users in the Femto-cell and macro-cell. Also, this improved optimization technique assures to reveal the mitigated network system in terms of signal to interference noise ratio (SINR), spectral efficiency, throughput and outage probability (OP) over the conventional methods.

Keywords: OFDMA-LTE, signal to interference noise ratio, bee colony algorithm, Genetic Algorithm optimization, femto-cell, macro-cell, cross tire interference.

INTRODUCTION

Recently, the world witnessed rapidly growing wireless technology and increasing demand of the wireless communication services [1]. Accordingly, wireless transmission techniques that promote spectrum usage efficiency and enable high data rate communication over multipath radio, such as, orthogonal frequency division multiple access (OFDMA) have found widespread deployment in current wireless transmission technologies [2-3]. One of the crucial issues in OFDMA transmission is power allocation of the available sub channels. Even though the OFDMA concept is simple in its basic principle, building a practical OFDMA system is far from being a trivial task without a well-devised RA algorithm [4]. In the case of a multiple-access network, a typical RA problem in OFDMA is based on assigning a subset of available sub-carriers to simultaneously transmit (and thus interfering) wireless terminals and (possibly jointly) adjusting the power amount over each used subcarrier in order to guarantee the minimum required Quality of service (QoS). An efficient algorithm for subcarrier selection can significantly increase the SINR, that is necessary to enhance the throughput in a dynamic scenario [5]. Similarly, regulating the transmit power in wireless cellular networks constitutes a key degree of freedom in the management of energy, interference and connectivity.

In the OFDM, different criteria to allocate the available resources can be performed depending upon whether the network is trying to maximize the overall data rate under a total power constraint, or to minimize the overall transmit power given a fixed data rate or bit error rate (BER). The water-filling (WF) criterion [6] is derived for Digital Multitone (DMT) modulation systems, which allocates the information bits to the users with highest signal-to-noise ratios (SNRs) carriers. In an OFDMA network, the BS must optimally allocate power and bits over different sub-carriers based on instantaneous channel conditions of different active wireless terminals. The only requirement is that the fading rate is not too fast (compared to the OFDMA symbol time), as instantaneous RA is impractical in the presence of rapidly-varying transmission channels of mobile terminals. Other impairments include interference management and limited resources, such as bandwidth and transmit power. This makes the link adaptation task much more challenging than in single-user systems [7].

In order to handle such critical situations and so to improve the signal-strength in restricted areas, the mobile operators need to come with an effective solution. Among the various solutions, deploying femto-cells are one of them [8]. Femto-cell s are nothing but a small low-cost base station with a short service range, usually from $10m$ to $15m$, and these cells are often referred as femto base station [9]. It can serve as a small range stationary or mobile data access point located on high user density hot spots [10]. Usually femtos are deployed in an ad hoc manner in contrast to deploy in a planned environment of macro cellular networks. Such deployments further degrade (increase or grade) interference, however, it also requires interference coordination as self-configuring and adaptive [11]. In recent days, interference alignment (IA) has been introduced as a coding technique to achieve high multiplexing gains within interference limited environments. The IA has to be based on a linear precoding at the transmitter side and zero-forcing equalization at the receiver [12].

The above methods have some constraints such as Throughput, inter and intra interferences. In order to overcome this constraint and to improve the OFDMA-LTE performance, GA-HBCCS-ORA technique is introduced. By applying a GA-HBCCS technique the optimal power values are updated to allocate all the users in the femto-cell and macro-cell. The GA-HBCCS technique improves mitigated network system performance in terms of SINR, spectral efficiency, throughput and OP.

LITERATURE REVIEW

S. Xiao *et al.* [13] maximized the throughput of the femto-cell while avoiding severe inter-tier interference with the macro-cell via joint sub-channel assignment and power allocation (PA). In this technique, Lagrangian dual method was used to decompose the original optimization problem into a primal problem and a dual problem. The concave-convex procedure transforms the non-convex primal problem into a tractable form through sequential convex approximations and then used the sub-gradient method to solve the dual problem. The major limitation of this technique is the sub-channel allocation problem that is not investigated since a single channel network is assumed.

Tehrani *et al.* [14] considered a general RA problem in a heterogeneous OFDMA based network consisting of imperfect FD macro BS and femto BSs and both HD and imperfect FD users. The author maximized the down-link and up-link weighted sum-rate of femto users while protecting the macro user's rates. The weights allow for users to utilize differentiated classes of service, accommodate both frequency or time division duplex for HD users, and prioritize up-link or down-link transmissions. The major limitation of this technique is high computational complexity.

Kaneko *et al.* [15] introduced a RA method for the down-link of an OFDMA-based macro-cell/femto-cell overlaid Heterogeneous Network. To mitigate the interference caused by femto-cell Base Stations (FBS) on nearby Macro-cell Users, conventional methods rely on the information of the interference channel states as well as Macro-cell Use allocation mapping provided by a control channel, causing a substantial overhead increase. The proposed method enabled the FBS to predict the sub channels likely to be used by its neighbour Macro-cell Use, based on their locally overheard Channel State Information (CSI), and to set appropriate constraints on those sub channels. This method leads to an unnecessary resource reuse limitation.

Zhao *et al.* [16] presented a joint admission control and a RA strategy for an orthogonal frequency-division multiple access-based femto-cell network. In this system, users were classified into two types for an OFDMA based femto-cell network: high-priority (HP) and low-priority (LP), of which HP users entitled to enjoy a more distinguished QoE in addition, an HP user has higher priority to access the network over all the LP users in the same contention region. The major limitation of this technique is computational complexity.

Liu *et al.* [17] introduced a simple and novel power control algorithm based on virtual proportional-integral (PI) controller for femto-cell networks, which extended the famous FM algorithm. Additionally, when the maximum power constraint was considered, a linear system with state saturation was established. The global asymptotic stability of the power equilibrium was verified based on the linear matrix inequality (LMI) algorithm. The major limitation if this technique is power consumption.

GA-HBCCS-ORA technique

The objective of the GA-HBCCS-ORA system is to reduce the interference occurred between the femto-cell and macro-cell. In communication systems, it is the average rate of successful message delivery over a channel. In our GA-HBCCS-ORA methodology, the system throughput is the important constraint to minimize the cross tier interference. Because of the system throughput and the interference are correlated. Therefore, one of the objective of this research work is to attain the maximum system throughput. Consider the System Multi user OFDMA system with Mitigate Interference, which is shown in the figure 1. The Resource of the system has been allocated by GA based HBCCS Technique with the help of existing allocated power, Distance and BER.

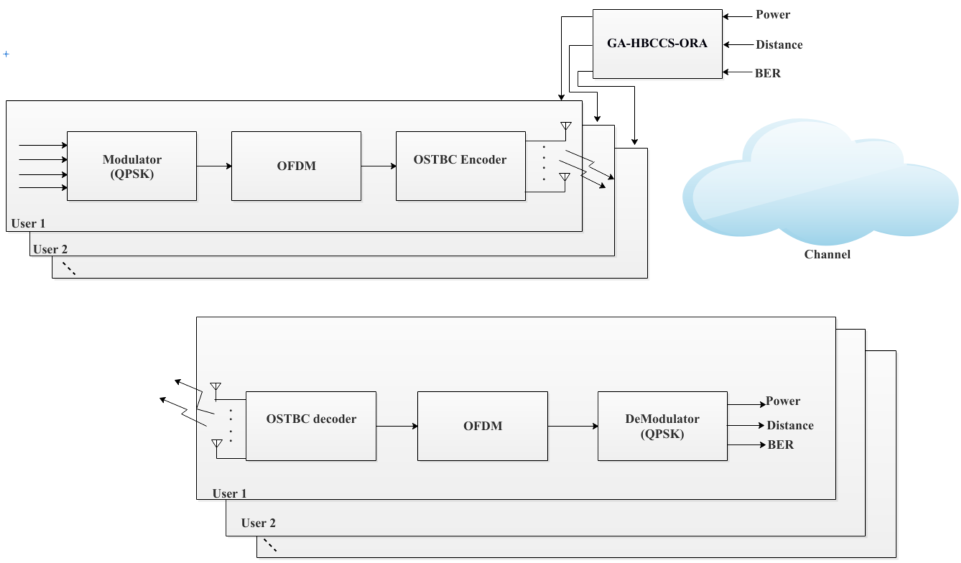

Figure 1. Block diagram of GA-HBCCS-ORA methodology.

In this system GA and HBCCS algorithms used for optimizing the resource, with the help of power distance and error rate. Both the algorithms separately optimize the power value. At the time of PA this system compares the GA output and HBCCS algorithm output, the lesser value will get allocated to the transmission. This method reduces the BER as well as improves the spectral efficiency and throughput.

Modulation

The data which is received from the turbo encoder is applied to the QPSK modulator for modulating the signal to obtain the respective coverage of signal transmission. In MIMO-MRC-OFDMA, the QPSK modulation is employed and it is a digital modulation technique. Quadrature means the signal shifts between the states of phases that are divided by 90°. QPSK increases the signal to 90° from 45° to135°, $-45°(315°)$, or $-135°(225°)$. There are two channels which is I and Q used in the QPSK modulation technique. QPSK transfers the 2 bits simultaneously over the AWGN channel. In this QPSK modulation two carrier frequencies are identical, but their respective phase is offset by90°. For each channel two carriers are added and it is assigned to the respective channel modulator and the bandwidth for this modulation is $2\,bits/second/Hz$. The constellation diagram for the QPSK modulation is given in the Figure 2.

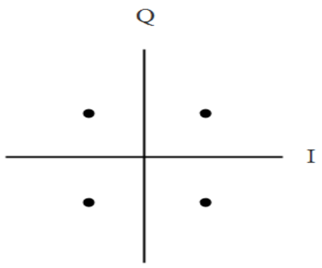

Figure 2. Constellation diagram for QPSK modulation.

Orthogonal Space Time Block Code scheme

After performing the modulation process, the data packets are sent to the OSTBC encoder and OSTBC decoder for encoding and decoding the data packets respectively. Assume that OSTBC has N_T of transmit antennas and N_R of receive antennas. The code which is used in the OSTBC is orthogonal and it obtains the full transmit diversity that is described by the amount of transmits antennas. OSTBC is a much more complex version of the Alamouti's space time code. The following matrix rows represents different time instant and the following matrix columns denotes the transmitted symbol along with each different antenna.

$$\begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1nT} \\ s_{21} & s_{22} & \cdots & s_{2nT} \\ \vdots & \vdots & \ddots & \vdots \\ s_{T1} & s_{T1} & \ldots & s_{TnT} \end{bmatrix}$$

OSTBC encoder is used for mapping the modulated symbols of transmission matrix. The encoder input symbols are separated into several symbols groups. The symbols employed in the group rely on the amount of transmit antennas and a mapping rule. A transmission matrix is$P \times N_T$, where $P$is the time slots and $N_T$is the transmit antennas. The different symbol columns are delivered over the different kind of antennas and also in dissimilar time slots different symbol rows are transmitted. OSTBC decoding is achieved by the maximum likelihood and linear processing of the receiver.

Consider the OFDM system has N amount of sub-carriers and within that sub-carriers only N_A amount of sub-carriers are active. The remaining sub-carriers are called as virtual sub-carriers derived from the equation (Eqn) (2).

$$N_V = N - N_A \qquad (2)$$

These virtual sub-carriers are employed as a frequency guard band with the $N_V/2$ amount of virtual carriers which is present at the both ends of spectral band. In transmitter, the bit streams are assembled and mapped into complex symbols. Consider, the delay spread of channel is lesser than the Cyclic Prefix (CP) length$L$. Two consecutive OFDM symbols are established an Alamouti code word that is produced after removing the CP.

The OFDM symbols transmitted through the OSTBC are expressed in the following Eq. (3).

$$S_j = \left[O_{N_V/2\times 1} S_j{}^{-T} O_{N_V/2\times 1}\right] \qquad (3)$$

Where, the guard band is represented as O's and the data vector of length is $\acute{S}_j$, it is calculated from the Eqn (2). In first OFDM symbol period, s_1 and s_2 are transmitted from the transmit antenna respectively. During the second OFDM period $-s_2$ and s_1 samples are transferred from the antenna 1 and 2 respectively. Time domain signal is obtained by using the IFFT operation in frequency domain signal. CP is added with the signal, when parallel to serial conversion occurred and then the overall length vectors ($N + L$ is transmitted simultaneously from the two transmit antennas. The encoding matrix of OSTBC encoder is given in the following Eq. (4).

$$S = \begin{pmatrix} s_1 & s_2 \\ -s_2 & s_1 \end{pmatrix} \qquad (4)$$

The obtained OFDM symbols are given in the following Eq. (5) and (6).

$$\mathring{y}_1 = h_{1,1}s_1 + h_{2,1}s_2 + n_1 \qquad (5)$$

$$\mathring{y}_2 = -h_{1,1}s_2 + h_{1,2}s_1 + n_2 \qquad (6)$$

Where, $\mathring{y}_1$ and $\mathring{y}_2$ are the received $N1$symbol period from antenna 1 and 2, $h_{j,k}$ describes as the NN transmission matrix from the k^{th} transmit antenna to the j^{th} receive antenna, n_1 and n_2 are $N1$complex gaussian random noise.

After performing serial to parallel conversion, the received time domain signal is converted into the frequency domain by using the FFT operation. The following Eq. (7) and (8) gives frequency domain signals.

$$y_1 = F\mathring{y}_1 + F\mathring{n}_1 \qquad (7)$$

$$y_2 = F\mathring{y}_2 + F\mathring{n}_2 \qquad (8)$$

The following Eq. (9) shows that the symbols from the OFDM.

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{1,1} & h_{2,1} \\ h_{2,2} & -h_{1,2} \end{bmatrix} . \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (9)$$

The received signal of Eq. (10) is achieved by rewriting the Eq. (9).

$$y = Hs + n \quad (10)$$

GENETIC ALGORITHM

GA was Introduced by John Holland in the 1970s. Over the years, GA became one of the most famous metaheuristics in problem solving. GA is a population based metaheuristic inspired by biological processes and natural evolution. It is guided by the survival of the fittest principle. In GA, we create a population of individuals. Each of them represents a solution for the particular problem. This is one of the main strengths of GA. At each step, GA can deal with a set of solutions rather than with a single one. This approach allows a better exploration of the search space. The individuals of the population are submitted to a set of genetic operations: representation, initialization, evaluation, selection, recombination and termination. Then, a new population is derived from the older one. The principle of survival of the fittest ensures the evolution of the solutions as the algorithm progresses. Figure 3 shows how GA works [18].

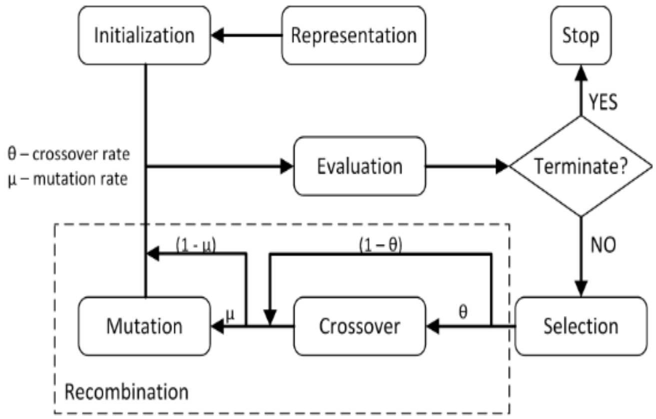

Figure 3. Genetic Algorithms working.

Hybrid Bee Colony and Cuckoo Search (HBCCS)

HBCCS is considered to be one of the most recent metaheuristic and/or Swarm Intelligent algorithms (SI) like GA, Particle Swarm optimization, Ant Colony Optimization (ACO), and Differential Evaluation (DE). A metaheuristic can have defined as an iterative generation process that guide a subroutine heuristic by combining intelligently different concepts to explore and exploit the search space to find optimal solutions. It's based on breeding and levy flight foraging behaviour of the cuckoo birds. The working of the HBCCS is shown in the figure 4.

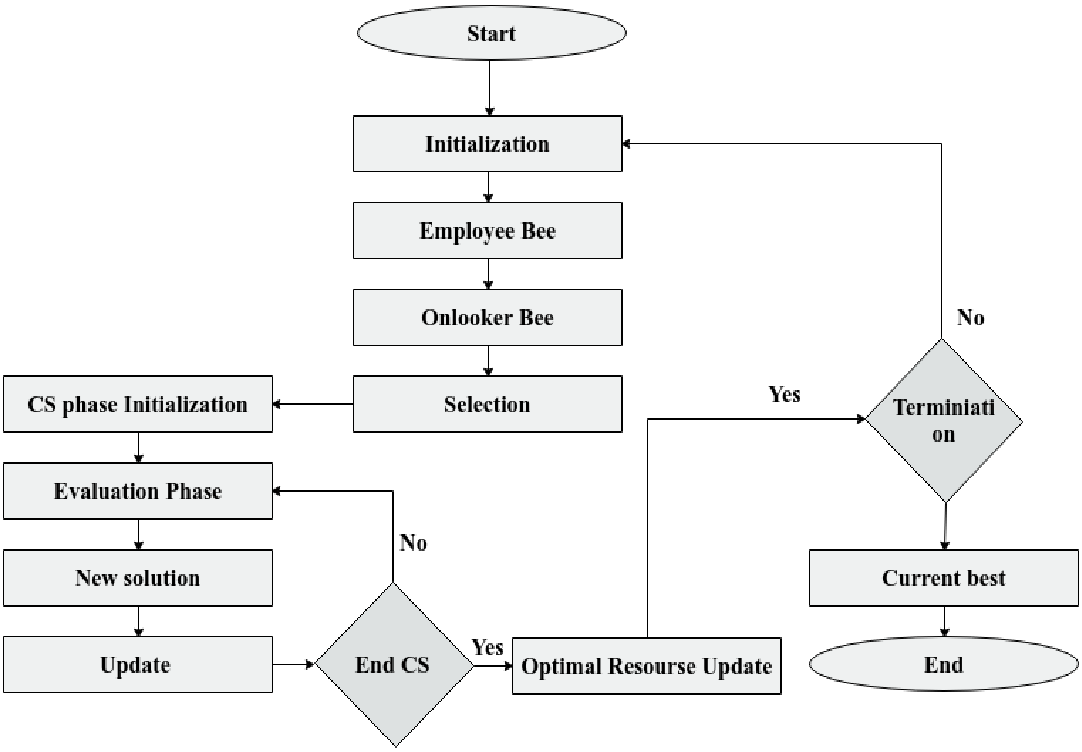

Figure 4. HBCCS Algorithms working.

RESULTS AND DISCUSSION

GA-HBCCS-ORA system was implemented by using MATLAB 2018a software tool for the simulation purpose in the Intel i5 desktop computing environment with 8 GB RAM memory capacity. In this GA-HBCCS-ORA system has majorly consists of Resource allocation with GA and HBCCS schemes in femto-cell network based OFDMA-LTE system.

Table 1. Simulation Parameters

GA-HBCCS-ORA system Testing	
Data bits	5000 bits data's (with pocket size of 25)
Sampling rate	1e6
Path delays	0 to 2e-6
Path gain	0 to -10
Modulation & demodulation	QPSK
Channel encoding & decoding	OSTBC
Data Encoding	Turbo coding
SNR value for analysis	-35:10:45
Total available Bandwidth	50 MHz
Maximum transmitted power	23 dBm
Macro cell coverage Radius	500 m
Number of macro cell base station	3
Maximum number of users in FC	5
Sub carrier Bandwidth	15 KHz
Maximum number of mobile users	50

In the simulations, the macro-cell has a coverage radius of 500 m. Each femto-cell has a coverage radius of $10m$. K FBSs and 50 macro users are randomly distributed in the macro-cell coverage area. The minimum distance between the MBS and a macro user (or an FBS) is $50m$. The minimum distance between FBSs is $40m$. Femto users are uniformly distributed in the coverage area of their serving femto-cell. Both macro and femto-cells employ a carrier frequency of $2GHz$, $B = 10MHz$, and $N = 50$. The AWGN variance is given by $\sigma 2 = BNN0$, where $N0 = -174\,dBm/Hz$. The Rayleigh-fading channel gains are modeled as unit-mean exponentially distributed random variables. The average channel gain (including pathloss and antenna gains) for indoor femto user and outdoor macro user are modelled as $\lambda d - 4$and $\lambda d - 3$, respectively, where $\lambda = 2 \times 10 - 4$. Besides, $\alpha$is selected as 4×104using the try-and-error method through simulations. The maximum transmit powers of a femto user and a macro user are set as 20 and 30 dBm, respectively. All mobile users are considered as with the QPSK modulation, OFDM. The users are transmitting the 5000 bit data with pocket size of 25. OFDMA-LTE environment the femto cell interfering users defines the user in the femto cell base station is conflict with macro cell base station. Because of the femto-cell user is in the coverage of macro-cell base station. Femto non interfering users means the user does not interfere with macro cell base station. The Convergence rate of HBCCS-ORA and GA-HBCCS-ORA is shown in the figure 5.

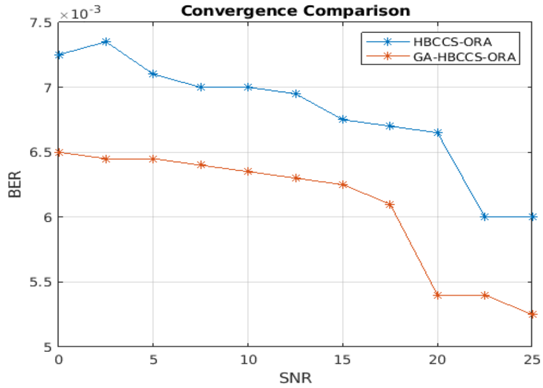

Figure 5. Convergence rate comparison.

Figure 6 shows the capacity of the macro-cell when the number of femto users per femto-cell increases from 1 to 6, for $K = 20,30$ and 50. It can be observed that the GA-HBCCS-ORA algorithm outperforms and HBCCS-ORA algorithm by up to a 23‰ increase in macro-cell capacity so the number of femto-cells users alsoincreases. Therefore, the GA-HBCCS-ORA algorithm is more and more superior compared to the UHBCCS-ORA algorithm.

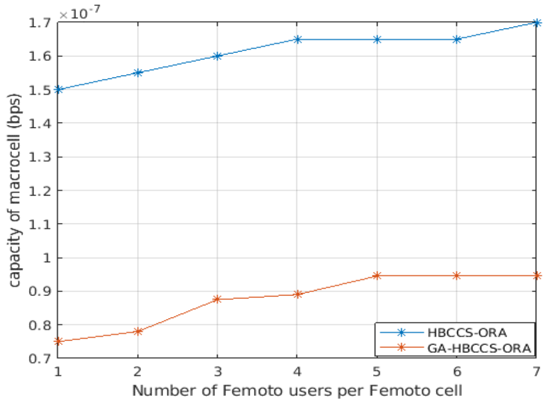

Figure 6. Capacity of macro-cell versus the number of femto users F in each femto-cell with the number of macro users$M = 50$

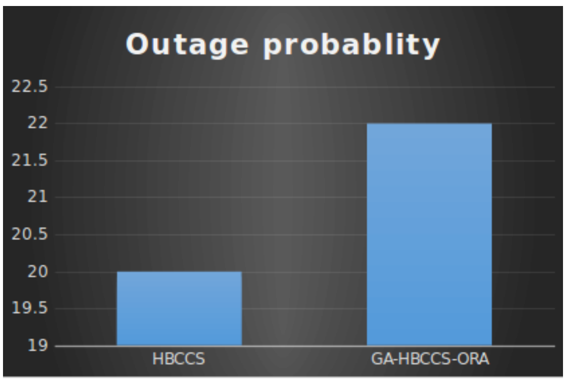

Figure 7. Outage Probability comparison

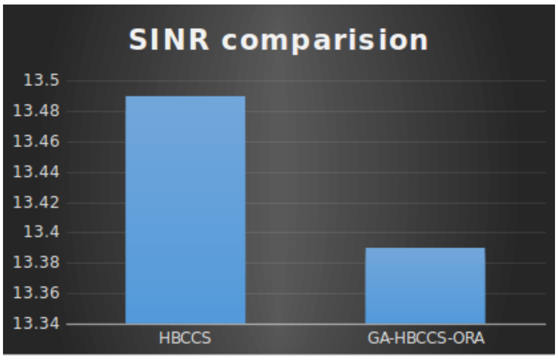

Figure 8. Signal-to-interference and noise ratio comparison.

Fig. 8 shows the s SINR of the connection between the base station k and user i ($SINR_i$) and OP (P_{out}). It describes when the $SINR_i$rapidly increased, the outage probability was reduced rapidly in our work compared with HBCCS methods. The value of outage probability of the users was achieved below zero in our work as shown in fig. 9.

CONCLUSION

In this paper, we investigated the RA in OFDMA-LTE environment. In this sense, we proposed a new technique based on GA and HBCCS. We considered a scenario with data transmission and evaluated the GA-HBCCS-ORA algorithm using Matlab and compared its performance against the HBCCS scheduling method. From results, we believed that GA-HBCCS-ORA can be an important tool in LTE up-link RA. In our evaluation, the GA-HBCCS-ORA algorithm presented a superior performance in the terms of SINR, Throughput, Spectral efficiency and OP.

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