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Artificial Bee Colony Optimization Based Dynamic Resource Allocation for OFDMA-Based Relay Networks

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Abstract: OFDM is becoming an active and promising domain for the next generation of wireless systems due to its intrinsic resistance to frequency selective multi-path fading and its flexibility in resource allocations. Recently, resource allocation in OFDM has been attracting various researches in the field of wireless networking. It has been observed recently that the integration of OFDM and relay networks are providing significant performance. A novel technique for resource allocation is presented in this study which dynamically allocates subcarriers, bits and power to the existing links based on instant channel state information. The main aim of this approach is to minimize the power required for the transmissions of the Base Stations (BS) and the Relay Stations (RS) through an efficient swarm intelligence based optimization technique. Artificial Bee Colony (ABC) is utilized in this approach for providing the optimized results. The performance evaluation of the proposed ABC based resource allocation technique suggests that the essential power required is lower than the power required by other existing resource allocation techniques in a defined scenario of a relay network.

Key words: OFDM, base station, relay stations, Artificial Bee Colony (ABC), allocation technique

INTRODUCTION

Conventional Network (CNT) and Relay Network (RNT) are the two significant forms of wireless cellular networks. In CNT, SS is directly linked to a Base Station (BS). A high capacity can be provided by a huge number of BSs per area. But a large number of BSs would increase the cost of a future network. RNT is the second capable kind of a future network where in addition to BSs and SSs, Relay Stations (RS) also exists (Muller *et al*., 2007a, b). A RS forwards messages between a source and destination.

Future Wireless Cellular Networks shall offer a high capacity in a given service area particularly in urban environments. High data rates are provided to a Subscriber Station (SS) also at the cell border. Frequency bands used by next generation networks are positioned at higher carrier frequencies than frequencies of today's wireless cellular networks. The coverage of a transmitter is minimized at higher carrier frequencies. Providing high data rates are quite tough at the cell border of huge cells (Muller *et al*., 2007a).

Ubiquitous high data rate coverage is the main focus of next generation wireless networks. Provided with the luxurious and scarce spectrum, attaining this goal needs high-spectral-efficiency approaches that depend on aggressive resource reuse (Salem *et al*., 2010a).

Ubiquitous coverage means that service has to be given to the users in the most unfavorable channel conditions through effective distribution of the high data rate (capacity) across the network. Rising capacity along with coverage in conventional cellular architecture dictates intense deployment of Base Stations (BSs) which results to be a cost-wise inefficient solution to service providers (Akyyildiz *et al*., 2005). A RS which is inexpensive with higher functionality than the BS is capable of delivering the high data rate coverage to remote areas in the cell. In the meantime, the Orthogonal Frequency-Division Multiplexing (OFDM) air interface is promising approach for providing significant performance for next generation networks. This is because of the reality that OFDM has the inherent capability to combat frequency-selective vanishing (Salem *et al*., 2010b).

Resource allocation in OFDM has become one of the active areas of research which refers to assigning subcarriers to consumers and choosing the power levels and the modulation approaches on the assigned subcarriers with the goal of satisfying individual consumer Quality of Service (QoS) necessities, e.g., data rate requirements (Zhang *et al*., 2011; Thanabalasingham, 2006).

The incorporation of OFDMA technology and the relay network structure provides a promising platform

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which offers nice flexibility in terms of resource allocation such as subcarrier allocation, scheduling and power control to achieve the multi-dimensional diversity gain (Salem *et al*., 2011; Le and Hossain, 2007).

A unique feature of OFDM based relaying is that the frequency diversity can be utilized by subcarrier pairing which matches the incoming and outgoing subcarriers at the relay based on channel dynamics and thus provides significant system performance in terms of resource allocation (Kivanc and Liu, 2000; Zhang and Letaief, 2002).

Thus, this research work focuses on the downlink of a cell in an OFDMA-based relay network. A BS and a fixed number of RSs are installed in the cell. Multiple Subscriber Stations (SSs) are positioned in the cell. Either, a direct connection (connection between the BS and a SS) or a two hop connection (connection between the BS and a RS and also between the RS and a SS) is utilized to serve SS from the BS (Muller *et al*., 2007a). This research mainly focuses on the resource allocation problems such as allocation of subcarriers, bits and power in such a manner that the transmit power of the BS and of the RSs are reduced.

The resource allocation issue is influenced by the requested data rate of each link and is also affected by constraint that a RS will not be able to transmit on a subcarrier and concurrently receive on another subcarrier so as to eradicate well-built intercarrier interference.

The toughness of the resource allocation issue is aggravated with the number of subcarriers, the probable number of bits per subcarrier and the number of links in a cell (Muller *et al*., 2007b).

This study focuses on a novel approach for resource allocation which allocates subcarriers, bits and power to the existing links. Evolutionary algorithms are observed to be efficient in the minimizing the power in various scenarios (Vishnu and Ajaykrishna, 2011; Tibin *et al*., 2011). An optimization problem is formulated using Artificial Bee Colony Optimization algorithm which reduces the power required for the transmissions of the BS and the RS.

LITERATURE SURVEY

Several researchers have proposed various techniques on resource management. An initial theory on throughput optimal scheduling in wireless multihop mesh networks was presented by Tassiulas and Ephremides (1992) which integrates queue-awareness into the scheduling policy which assigns resources vigorously to multicommodity flows. The researchers indicated that maximizing the sum of a queue length based drift metric over all node pairs result in maximum throughput which stabilizes all network queues under the biggest group of mean exogenous arrival rates for which the network queues can be stabilized. Yet, the researchers suggested that developing competent algorithms in order to solve the optimization problem given the constraint set imposed by the system model of each specific application is vital for implementation. Various researches have utilized throughput-optimal scheduling thereafter proposing scheduling policies for adhoc networks, non-OFDMA or traditional (non-relaying) cellular networks with various optimization algorithms. For example in Kobayashi and Caire (2007) and Parag *et al.* (2005), traditional cellular SDMA/TDMA and OFDMA networks are respectively regarded thus eradicating the joint routing and scheduling feature of such policies and limiting the queue stabilizing opportunities to the resource allocation at the BS.

As fairness is vital to realize the preferred service ubiquity and reliability in cellular networks, it should be observed that throughput-optimal policies are not fairness oriented in principle as they focus at stabilizing all user queues under any heterogenous traffic flows with in the system's capacity region. Thus, a congestion control method is presented by Eryilmaz and Srikant (2007) for a traditional cellular network to focus on user fairness via traffic policing if the arrival rates at the BS are adaptive.

Neely *et al.* (2005) presented a centralized Dynamic Routingand Power Control Policy (DRPC) in a single-carrier ad hoc network with multi-product flows, rate adaptation and node power budgets. In each time slot, the DRPC handles a one-shot optimization to assign power to a group of links with the selected products such that the sum metric is maximized. Neely did not recommend any techniques to handle such an optimization under the node power constraints and the co-channel interference leading the attainable rates of these links. Thus, when the power control dimension is taken into account, a centralized joint routing and scheduling approach is presented by Viswanathan and Mukherjee (2005) for the downlink of a single carrier CDMA cellular relay network under symmetric traffic arrival techniques. Viswanathan and Mukherjee deduced that throughput optimal scheduling is an efficient technique in such a scenario. It is implicit that a route to the User Terminal (UT) may consist of an indefinite number of hops. The approach is highly complex and it is not appropriate to multi-carrier systems.

OVERVIEW OF OFDM

Making use of the dynamism in wireless channels, OFDM subcarriers can be adaptively altered and allocated to the best Wireless Subscriber (WS) to attain efficient frequency and multi-user diversity efficiency. OFDM is a multi-carrier transmission scheme where the bandwidth is partitioned into several non-interfering narrow band subcarriers (Flarion, 2003). Each user can be assigned one or more subcarriers for data transmission. The resources assigned in an OFDM System are the subcarriers and the transmit powers. OFDM has been applied in various domains which comprises of digital audio/video broadcasting (ETSI EN 300 401, 2006; ETSI EN 300 744, 2006) and wireless LANs (IEEE Std. 802.11g, 2003). It has also been considered as the access technique for future systems such as WiMAX (IEEE Std. 802.16e, 2006).

Orthogonality of subcarriers: The main benefit of OFDM is the effective utilization of the available frequency spectrum. In a traditional multi-carrier system, the frequency band is partitioned into non-overlapping subcarriers to remove the cross-talk between subcarriers known as Inter Carrier Interference (ICI). This non-overlapping approach of the subcarriers results in incompetent utilization of the available spectrum.

Alternatively, the overlapping of the spectrum of the subcarriers is facilitated by OFDM which provides high spectral efficiency. For this process, ICI between subcarriers must be lessened. This is done by making the subcarriers mutually orthogonal. The orthogonality between subcarriers is maintained by choosing the spacing between the subcarriers. The orthogonality of the subcarriers denotes that each subcarrier has an integral number of cycles over a symbol period. As a result, there is a difference of an integral number of cycles between any two subcarriers over a symbol period (Wu and Zou, 1995). Figure 1 shows an instance of an OFDM signal spectra. By means of perfect synchronization at the receiver, the data on each subcarrier could be decoded effectively without the interference from other subcarriers.

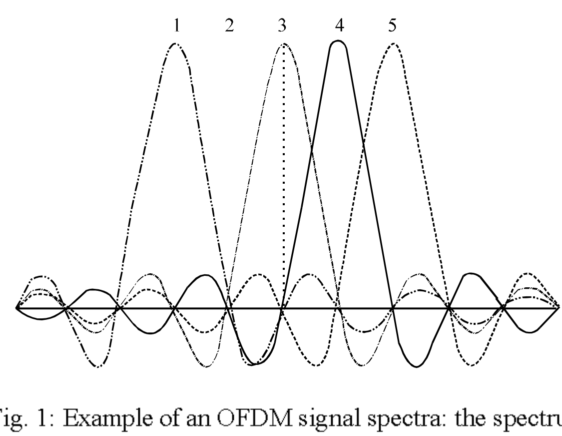

Fig. 1: Example of an OFDM signal spectra: the spectrum of each subcarrier has a null at the center frequency of each of the others

FORMULATION OF THE RESOURCE ALLOCATION PROBLEM

The cell of the considered relay network is formulated as follows. A BS and a number of RSs and of SSs are in the cell. A direct or a two hop connection is formed from the BS to each SS by means of the assignment algorithm given by Muller *et al.* (2007a, b). An index k = 1, 2..., K is used to denote all the K links of the cell. The links from the BS to a RS or to a SS are grouped in the set K_1. The links between all RSs and the SSs are in the set K_2. An OFDMA System is taken into account with N subcarriers and a subcarrier index n = 1, 2,..., N is defined. The BS assigns subcarriers, bits and power to the links. The BS has ideal facts about the noise power and the instant channel gain of all subcarriers of the links. On each subcarrier n of a link k the same noise power σ^2_k is assumed. The BS knows about a requested data rate Rk for each link. A frame based transmission is applied. A frame comprises of S slots where a slot has the duration of an OFDM symbol. A frame based time division multiplexing is exploited to partition reception and transmission of a RS. A frame is partitioned into two subframes. The first subframe comprises of S_1 slots with index 1 to S_1. In the first subframe, the BS broadcasts to the RSs and to those Sss which use direct connections. The BS exploits all N subcarriers. During the second subframe of length $S_2 = S-S_1$, the RSs transmit from slot S_1+1 until slot S. The subframe index is represented by m, i.e., $m\in\{1; 2\}$. The coherence time of the channel is assumed to be larger than the duration of a frame. A subcarrier, bit and power allocation technique is applied to a complete frame. Each subcarrier can be assigned only to one link in a subframe. A subcarrier may be loaded with no data or with a modulation symbol carrying a number of bits based on the selected constellation size of the modulation approach. It is assumed that QPSK, 16-QAM or 64-QAM can be used. The number of bits loaded on a subcarrier during a slot is c. It is observed that c can denote coded as well as uncoded data. The possible values of c are given as the elements of a set called D = {0, 2, 4, 6}. The bits c must be transmitted based on a maximally tolerated bit error probability on a subcarrier. The function f_k (c) illustrates the necessary receive power on a subcarrier for the reception of c bits per symbol based on a noise power and a tolerated bit error probability on link k. It is derived from the formula of the bit error probability P_e of QPSK and QAM depending on the signal to noise ratio (Proakis, 1995), the function is given by:

$$f_k(c) = \frac{(2^c - 1)\sigma_k^2}{3}\left(Q^{-1}\left(\frac{P_e}{4}\right)\right)^2 \quad (1)$$

where, Q^{-1} (.) represents the inverse complementary error function. The function $f_k(c)$ is monotonically increasing with $f_k(0) = 0$. The transmit power needed on a subcarrier is given by:

$$P_{k,m} = \frac{f_k(c)}{\alpha_{k,n}^2} \quad (2)$$

where, $\alpha^2_{k,n}$ denotes the instantaneous channel gain of link k and subcarrier n. An indicator variable is introduced which illustrates if subcarrier n is assigned to link k and if subcarrier n is loaded with c bits. The indicator $u_{k,n,c}^{(m)}$ variable is defined as:

$$u_{k,n,c}^{(m)} = \begin{cases} 1 \text{ if c bits are mapped on subcarrier n allocated to link k} \\ 0 \text{ otherwise} \end{cases} \quad (3)$$

The transmit power used in subframe m is given by:

$$P_m = \sum_{k \in K_m} \sum_{n=1}^{N} \sum_{c \in D} \frac{f_k(c)}{\alpha_{k,n}^2} u_{k,n,c}^{(m)} \quad (4)$$

where, P_1 is the transmit power of the BS and P_2 is the transmit power of the RSs. Since, bits of a link are only ransmitted in one of the two subframes, an instantaneous data rate:

$$R_k^{(m)} = \frac{S}{S_m} R_k \quad (5)$$

of a link is defined where $R^{(m)}_k$ gives the data rate which is obtained in the subframe m in which the link k is served. The instant data rate of a link k during the frame in which this link shall not be served is zero.

Minimizing the transmit power of the BS and the power of the RSs is written as:

$$P_{min} = \min_{u_{k,n,c}^{(m)}} \max\{P_1, P_2\} \quad (6)$$

$$\sum_{n=1}^{N} \sum_{c \in D} c u_{k,n,c}^{(m)} \geq R_k^{(m)};\ \forall k \in K_m;\ m \in \{1;2\} \quad (7)$$

$$\sum_{k \in K_m}^{N} \sum_{c \in D} u_{k,n,c}^{(m)} = 1;\ \ \forall n, m \in \{1;2\} \quad (8)$$

The optimization problem (Eq. 6) is selected as a min-max optimization to facilitate that the power of the BS and the sum of the power of all RSs is reduced without favoring one of them. The constraint (Eq. 7) assures that each link obtains its requested data rate. The constraint (Eq. 8) denotes that a subcarrier is assigned to only one link in a subframe. Problem (Eq. 6) can be solved by an efficient search algorithm. As the complexity of such an exhaustive search algorithm increases exponentionally with the number of variables such a solution is not applicable in practice.

DYNAMIC RESOURCE ALLOCATION METHOD

In order to assure an appropriate solution of problem (Eq. 6), the problem is split into the following subproblems: Initially, the subframe sizes S_1 and S_2 are obtained. The solution of this subproblem is provided by an efficient algorithm which adjusts the subframe size to the channel state and the requested data rate on the links. Secondly, a dynamic subcarrier, bit and power allocation is applied. For this, an algorithm defined for a network without RSs is adapted to a relay network. For this operation, an efficient optimization technique is adapted in this study.

Subframe size: The subframe sizes S_1 and S_2 must be obtained without knowing the allocation of the subcarriers to the links, the bits transmitted on a subcarrier or the power used on a subcarrier. Therefore, the necessary power of the BS and of the RSs is evaluated rather than accurately determined. For all possible sizes of the subframes, the maximum of the transmit power of the BS and of the RSs is estimated. The subframe size is selected which results in smallest maximum.

The evaluation of the necessary transmit power depends on a representative number of bits per subcarrier and on a representative channel gain of a link. The representative channel gain of a link is estimated by:

$$\bar{\alpha}_k^2 = \frac{1}{N} \sum_{n=1}^{N} \alpha_{k,n}^2 \quad (9)$$

In (Eq. 9), the arithmetic mean value is selected were in each channel has an equal weight as no knowledge of the subcarrier allocation is given. The representative number of bits per subcarrier is $\bar{c}_m$ with $\bar{c}_m \in R^+$. In order to identify S_1, each subcarrier is assumed to carry $\bar{c}_m$ bits.

The number B_m of bits which must be transmitted in a subframe is equal to the number of slots in a subframe times the sum of the requested data rates in a subframe given by:

$$B_m = S_m \sum_{k \in K_m} R_k^{(m)} \quad (10)$$

For all possible sizes of the first subframe and the corresponding sizes of the second subframe, the representative number of bits is calculated by:

$$\bar{c}_m = \frac{B_m}{NS_m} \quad (11)$$

The smallest possible size of the first subframe is given if the number B_1 of bits is provided by loading all subcarriers with the maximum number of bits defined in D. The size of the first subframe is lower bounded by:

$$S_1 \geq \left\lceil \frac{B_1}{N\max\{D\}} \right\rceil \quad (12)$$

where, $\lceil\cdot\rceil$ represents the rounding to the next greater integer value and $\max\{D\}$ is the greatest element of the set D. The size S_2 is given by the equation . $S_2 = S-S_1$. The size $S_1$is upper bounded by assuming that the highest number of bits is loaded on all subcarriers in the second subframe, i.e.:

$$S_1 \leq S - \left\lceil \frac{B_2}{N\max\{D\}} \right\rceil \quad (13)$$

The calculation of the transmit power of the BS and the RSs, respectively is given by:

$$\bar{P}_m = \sum_{k\in K_m} \frac{R_k}{\sum_{l\in K_m} R_l} \frac{N f_k(\bar{c}_m)}{\bar{\alpha}_k^2} \quad (14)$$

An arithmetic mean value is selected in which each power is weighted by its normalized requested data rate as it is assumed that the higher the data rate of a link the more subcarriers are allocated to that link. Out of all possible combinations of S_1 and S_2, the combination $(S^{\cdot}_1; S^{\cdot}_2)$ is chosen which fulfills:

$$S_1 : S_2 = \arg\min_{S_1, S_2} \max\{\bar{P}_1, \bar{P}_2\} \quad (15)$$

Subcarrier, bit and power allocation: By considering the Eq. 14, the power of the BS and of the RSs can be reduced separately by identifying an optimal subcarrier, bit and power allocation per subframe, i.e., the optimization problem (Eq. 6) is divided into two optimization problems. The problem in allocating subcarriers, bits and power in such a manner that the transmit power is reduced subject to a requested data rate on each link is formulated and solved for a scenario without RSs (Kim *et al*., 2006). In this approach, this problem is solved in a scenario of a relay network. Keeping the constraints (Eq. 7) and (Eq. 8), the power used in a subframe is minimized given by:

$$P^{(m)}_{min} = \min_{u^{(m)}_{k,n,c}} \sum_{k\in K_m} \sum_{n=1}^{N} \sum_{c\in D} \frac{f_k(c)}{\alpha^2_{k,n}} u^{(m)}_{k,n,c} \quad (16)$$

Subject to:

$$\sum_{n=1}^{N} \sum_{c\in D} c u^{(m)}_{k,n,c} \geq R^{(m)}_k ;\ \forall k \in K_m \quad (17)$$

$$\sum_{k\in K_m} \sum_{c\in D} c u^{(m)}_{k,n,c} = 1;\ \forall n \quad (18)$$

Different to problem (Eq. 6), the subframe size is fixed. Subcarriers, bits and power are assigned independently in both subframes. During the first subframe, BS is the only transmitter present with multiple receivers such as RSs or SSs.

The proposed approach employs subset based ABC algorithm to solve this optimization problem and search for optimal set of optimal subcarrier, bit and power allocation per subframe.

ABC based optimization algorithm for power reduction: A modeling of artificial bee colony system is seen in Fig. 2. An efficient optimization algorithm that utilizes the bee behavior in food forging is used in this approach for optimization of the subcarrier, bit and power allocation. The major steps of the algorithm are as follows:

- Initialization
- Repeat
- Place the employed bees on their food sources
- Calculate the probability values
- Place the onlooker bees on the food sources
- Send the scouts to the search area for discovering new food sources
- Memorize the best food source found so far
- Until a termination is satisfied and output the best food source found so far

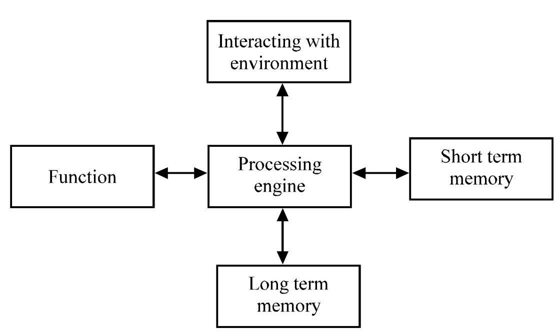

Fig. 2: Architecture of Artificial Bees'Colony System

Three types of bees such as employed, onlooker and scouts are involved in this process. There is a different role for each bee in the optimization process. Employed bees remain above the nectar source and keep the adjacent sources in memory. Onlooker bees obtain that data from employed bees and formulate a resource choice to gathe the nectar. Moreover, the scout bees are very much responsible for calculation. The algorithm consists of three steps. Employed bees are sent to scamper for resources and the amount of nectar is determined in the initial step. In the second step, onlooker bees build a resource option suitable to the data they obtain from determining new nectar resources. Finally, in the third step, one of the employed bees is selected randomly as a scout bee and it is sent to the sources to discover new sources (Ravi and Duraiswamy, 2011). Half of the bees in the colony are chosen as employed and others are considered as onlooker bees in the algorithm. Thus, the number of employed bees is equal to the number of nectar sources. The food sources in this technique refer to the probable solutions of the issue to be optimized. The amount of nectar which belongs to a source represents the quality value of that source as shown in Fig. 3 (Ravi and Duraiswamy, 2011).

In the initial step of ABC, random solutions are generated in the particular range of the variables x_i (i = 1,...., S). In the next step, novel sources are determined by each employed bee whose total is equivalent to half of the total sources. Equation 19 determines a new source.

$$V_{ij} = x_{ij} + \varphi_{ij}(x_{ij} - x_{kj}) \quad (19)$$

In Eq. 19, k is equal to (int (rand×S) +1) and j is equal to 1,..., D. After creating v_i, they compared x_i solutions and the best one was considered as the source.

In the subsequent step, a food source is selected with the probability by means of Eq. 20 (Ravi and Duraiswamy, 2011).

$$P_i = \frac{f_i t_i}{\sum_{j=1}^{SN} f_i t_j} \quad (20)$$

The scout bees are responsible for random studies in each colony. Scout bees do not make use of any pre-information when they are searching for nectar sources and as such, their exploration was done randomly (Omkar and Senthylnath, 2009). The scout bees are selected among the employed bees based on the limit parameter. The source is said to be eliminated if a solution that represents a source is not realized with specific number of trials. The bee of that source identifies new source as a scout bee. The number of incomings and outgoings to a source is attained by the limit parameter. Equation 21 is used to discover a new source of a scout bee (Ravi and Duraiswamy, 2011):

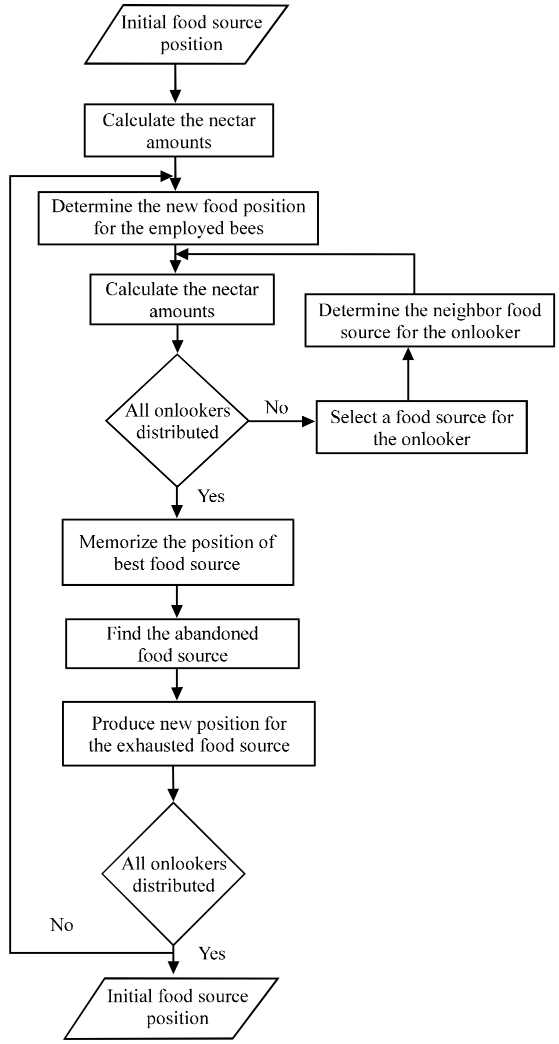

Fig. 3: Work flow of ABC algorithm

$$xij = xj^{min} + (xj^{max} - xj^{min}) \times rand \quad (21)$$

In ABC, the employed and the onlooker bees are involved in the operation process and the scout bees are used in the process of investigation. Bees focus mainly on the maximization of the energy function E/T indicating the quantity of the foods that are brought to the nest. The maximization of the objective function is F (θ_i), where $\theta_i \in R^p$ is done in the maximization problem. θ_i denote the position of the ith source, in which F (θ_i) represent the nectar amount in this source and it is proportional with

E (θ_i). P (c) = {θ_i (c)|i = 1, 2, ...S} represents the population of the sources which comprises of the locations of all the sources. Selecting a source of onlooker bees is based on the value of F (θ). If there are additional nectar amount of a source, it means that there is more probability that the source would be chosen. Thus, the likelihood of choose a nectar source in the position is (Ravi and Duraiswamy, 2011):

$$P_i = \frac{F(\theta_i)}{\sum_{k=1}^{S} F(\theta_k)} \quad (22)$$

After the onlooker bee examines the dance of the employed bees and chooses the source with the equality (Eq. 22) it discovers a neighboring source and takes its nectar. The location information of the selected neighbor is calculated by the following equation (Ravi and Duraiswamy, 2011):

$$(c+1) = \theta_i(c) \pm \phi(c) \quad (23)$$

ϕ (c) is assessed by considering the difference of certain parts of θ_i (c) and θ_k(c) in which k represents different from i are randomly formed indices of a solution in the population. If the nectar amount of θ_f (c+1), F (θ_f (c+1)) is greater than the nectar amount in the position θ_i (c) then the bee goes to its beehive and shares this information with the other bees and stays θ_f(c+1) in the mind as a new position. Otherwise, it keeps θ_f(c) in mind. If the nectar source of the position θ_f is not realized by the number of limit parameter, then the source in the position θ_i is discarded and the bee of that source becomes scout bee. The scout bee produces random explorations and discovers a new source and the new found source is assigned to θ_i. The algorithm iterates to the desired cycle number and the sources having the best nectar in minddenote the possible values of the variables. The solution of the object function is denoted by the attained nectar amount (Ravi and Duraiswamy, 2011).

The system is solved for the optimal resource allocation which allocates subcarriers, bits and power to the existing links to solve the optimization problem.

PERFORMANCE EVALUATION

Scenario: The proposed resource allocation approach through ABC isevaluated in a cell in which a BS and two RSs are deployed. The cell comprises of three hexagons which are equal in size. A BS is positioned in the center of one hexagon. The RSs are positioned in the centers of the neighboring hexagons. The SSs are uniformly distributed in this case and allocated to the BS or RSs based on a best server algorithm (Yanikomeroglu, 2002). The parameters chosen for the evaluation are shown in Table 1.

The parameters denote a general OFDMA System with fundamental features of a system according to IEEE 802.16, LTE or WINNER. The channel between BS and RS is modeled by a line of sight scenario called B5a and defined by WINNER (2005).

The channels between BS and SS and RS and SS are modeled by a non-line of sight scenario called C2 and defined by WINNER (2005). An antenna gain between BS and RSs is assumed to obtain an enhanced channel condition on the first hop of a two-hop connection. An omnidirectional antenna is employed for the transmissions between the BS and a SS and between a RS and a SS. The sum of the requested data rates of all SSs called sum rate is always constant to make the results comparable when the number of SSs is altered. In order to consider SSs with different data rate requests, an efficient traffic model is applied in which the requested data rate of a SS is given by a random segment of the sum rate which can be between 0 and 100%. The transmission between two nodes is only trustworthy based on a given bit error probability given in Eq. 2. A bit error probability $P_{e,c}$ maximally tolerated on a connection is given. For a two hop connection, the maximally tolerated bit error probability is well approximated (Ferrari and Tonguz, 2007) by the following equation:

$$P_{e,c} = 1-(1-P_e) \quad (24)$$

Evaluation results: The performance of the proposed resource allocation approach using subset based modified ABC is compared to the following existing resource allocation techniques:

Table 1: Parametes used for the evaluation

Parameters	Values
Side length of hexagon	400 m
Bandwidth	5 MHz
Power of White Gaussian noise	-99 dBm
Number of subcarriers N	128
Path loss from BS to RS in dB where d is the distance in meters	$38.5+23.5\log_{10}$ (d)
Path loss from BS to SS and from RS to SS in dB	$38.4+35\log_{10}$ (d)
Standard deviation log-normal fading between BS and RS	3.4 dB
Standard deviation log-normal fading between BS and SS and between RS and SS	8 dB
Antenna gain between BS and RS	17 dBi
Requested sum rate in cell	192 bits/slot
Maximally tolerated bit error probability per connection $P_{e,c}$	10^{-2}
Frame duration	40 slots

- Near optimum
- Fixed subframe size
- Static
- OFDMA-based relay networks
- ACO

The near optimum approach solves the problem (Eq. 6) by testing all possible combinations of the subframe sizes S_1 and S_2. For all combinations, the problem (Eq. 16) is handled by a suboptimal approach as by Kim *et al.* (2006) and is not optimally solved to minimize complexity. The near optimum technique is a close approximation to the optimal solution of problem (Eq. 6) as the difference between the optimal solution of problem (Eq. 16) and its suboptimal solution is <0.25 dB in the analysis of Kim *et al.* (2006). In fixed subframe size technique, the frame is partitioned into two subframes of equal size.

In the Static Method, the frame is also partitioned in two subframes of equal size. The number of subcarriers allocated to a link is proportional to the requested data rate on that link, i.e., if a link requests 40% of the data rate in a subframe, the link is allocated 40% of the subcarriers.

The subcarriers are selected without considering channel state information. The same number of bits is assigned to each subcarrier which must be two, four or six bits. The power is assigned to the subcarriers such that the maximally tolerated bit error probability and the requested data rate are achieved.

In Fig. 4, the Cumulative Distribution Functions (CDFs) of the maximum out of the transmit powers of the BS and the sum of the powers of the RSs are given for the introduced methods. The connections of eight SSs are considered within a frame. It is observed from the figure that the median of the proposed ABC based OFDM relay is lesser than the other approaches taken for comparison.

Performance comparison of optimization technique: The performance of the proposed subset based ABC algorithm for OFDMA-Based Relay Networks is compared with the Linear-Programming (LP) optimization technique and Ant Colony Optimization approach for OFDMA. It is observed from the Fig. 5 that the proposed subset ABC approach provides better convergence when compared with the linear programming approach and ACO. The proposed ABC approach takes 60 iterations for convergence where as the linear programming approach takes 90 iterations for convergence and ACO takes 70 iterations. Thus, ABC provides better convergence performance.

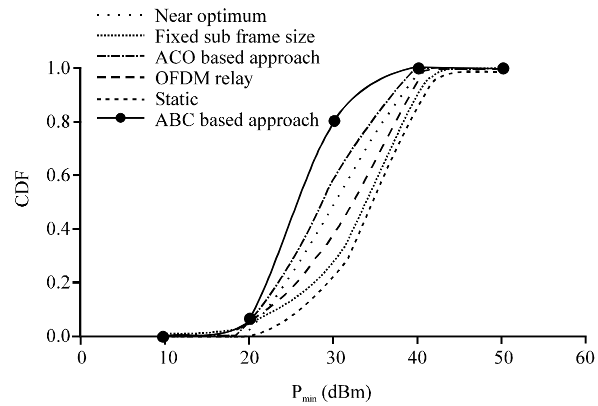

Fig. 4: CDF of the maximum out of the transmit powers of the BS

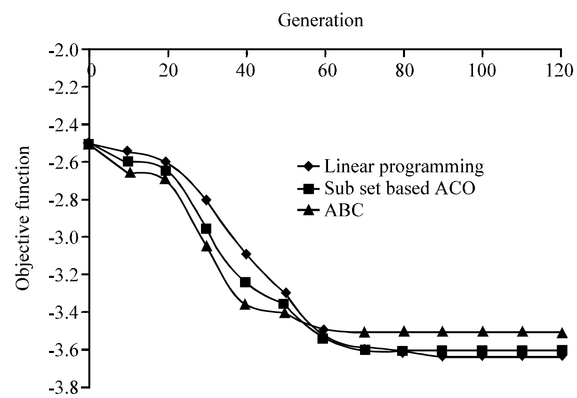

Fig. 5: Comparison of objective function of the optimized technique

CONCLUSION

OFDMA has been regarded as the most appropriate air-interface approach for the ever-growing wireless access networks and standards because of its reliability and unique characteristics. This study investigated the process of allocating subcarriers, bits and power dynamically in an OFDMA based relay network with the focus of minimizing the power of the BS and the RSs in a cell. A suitable resource allocation technique based on efficient swarm intelligence based optimization technique is presented taking into account a requested data rate and that a RS cannot transmit and receive at the same time. ABC is presented in this study to optimize the subcarriers, bits and power allocation. The presented resource allocation technique indicates optimum performance in a case denoting fundamental features of a system according to IEEE 802.16, LTE or WINNER. The performance of the proposed ABC optimization based approach is observed to be better than ACO and the other existing approaches. The future research of this approach would be to utilize advanced optimization techniques.

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