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Intelligence Swarm Techniques Based Dynamic Subcarrier, Bit And Power Allocation For Of DMA-Based Relay Networks

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is a reliable solution for future wireless communication networks. OFDM can provide a high performance physical layer and medium access control due to its capability to combat intersymbol interference and multipath fading. The toughest concern in OFDM systems is the problem of subcarrier and power allocation in a multiuser network to reduce the total transmit power and maximize the total data rate or a utility function of data rate of users. Relay Network is considered as a capable kind of a future network where in addition to BSs and SSs, Relay Stations (RS) also exists. A RS forwards messages between a source and destination. Relay Stations (RSs) and OFDM have become promising domain for the future generation of wireless systems due to its inherent resistance to frequency selective multi-path fading and its flexibility in resource allocations. In recent times, resource allocation in OFDM has been attracting several researches in the field of wireless networking. It has been observed recently that the integration of OFDM and relay networks is providing considerable performance. In this research, comparative analysis is carried out by comparing the performance of the two optimization techniques namely, Modified Ant Colony Optimization (ACO) and Artificial Bee Colony (ABC). The performance of both the approaches is compared in terms of Cumulative Distribution Function (CDF), bit error rate, convergence behaviour and delay rate. Based on the evaluation results it is confirmed that ABC performs better than the ACO.

Keywords: OFDM, Base Station, Relay Stations, Artificial Bee Colony (ABC), Ant Colony Optimization (ACO).

Introduction

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. Future Wireless Cellular Networks shall offer a high capacity in a given service area particularly in urban environments [1]. 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 [2].

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 [3].

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 [4]. 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, 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 [5].

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 [6, 7, 8].

The incorporation of OFDMA technology and the relay network structure provides a promising platform, which offers nice flexibility in terms of resource allocation, such as subcarrier allocation, scheduling and power control to achieve the multi-dimensional diversity gain [9, 10].

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 [11, 12].

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 [13]. 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 [13].

In this research, comparative analysis is carried out by comparing the performance of the two optimization techniques namely, Artificial Bee Colony (ABC) and Modified Ant Colony Optimization (ACO).

Orthogonal Frequency-Division Multiplexing

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.

Orthogonal Frequency Division Multiplexing (OFDM) is an essential technique for communicating over frequency selective channels [14]. By partitioning the available carriers into orthogonal, non-interfering subcarriers and adopting a parallel transmission approach, it provides better resistance to the multipath fading effects of the wireless channel than single carrier transmission systems [15]. OFDM is extensively deployed in commercial systems such as xDSL modems [16] and low mobility wireless LANs IEEE Std. 802.11g, (2003) [17]. It is also a part of WiMax, and a strong candidate for future wireless cellular systems [18].

Though OFDM typically multiplexes low rate data substreams from a single user onto all the subcarriers, a cellular network can use Orthogonal Frequency Division Multiple Access (OFDMA), in which the data streams from various users are multiplexed onto subsets of the subcarriers.

OFDM is a modulation approach as well as a multiple access approach. As a modulation approach, it can significantly deal with undesirable environmental states, while as a multiple access approach it provides high spectral efficiency and diversity.

OFDM is a special form of multi-carrier transmission approach. It offers better spectral competence over the conventional multi-carrier systems. The fundamental concept of OFDM is to divide a high rate data stream into a huge number of lower rate data substreams and alter them onto a number of particularly designed carrier frequencies called subcarriers. The data is transmitted concurrently over these parallel 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. [19].

Literature Survey

Several researchers have proposed various techniques on resource management. This section discusses about some of the techniques related to the power allocation in wireless networks.

An initial theory on throughput optimal scheduling in wireless multihop mesh networks was presented in [20], which integrates queue-awareness into the scheduling policy which assigns resources vigorously to multicommodity flows. The authors 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 authors 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 [21] and [22], 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 heterogeneous traffic flows within the system’s capacity region. Thus, a congestion control method is presented in [23] 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., [24] presented a centralized Dynamic Routing and Power Control Policy (DRPC) in a single-carrier adhoc 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 et al., 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 in [25] for the downlink of a single carrier CDMA cellular relay network under symmetric traffic arrival techniques. In [25] 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.

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 in [1]. 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_k^2 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 [26], the function $f_k(c)$ is given by

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

where $Q^{-1}(\cdot)$ 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

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

where $\alpha_{k,n}^2$ 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 variable $\mathrm{u}_{\mathrm{k,n,c}}^{(\mathrm{m})}$ is defined as

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

The transmit power used in subframe m is given by

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

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 $\mathrm{R}_{\mathrm{k}}^{(\mathrm{m})}$ 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

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

$$\sum_{n=1}^{N} \sum_{c \in D} c u_{k,nc}^{(m)} \geq R_k^{(m)}; \forall k \in K_m; m \in \{1; 2\} \quad (6b)$$

$$\sum_{k \in K_m}^{N} \sum_{c \in D} u_{k,nc}^{(m)} = 1;\ \forall n; m \in \{1; 2\} \quad (6c)$$

The optimization problem (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 (6b) assures that each link obtains its requested data rate. The constraint (6c) denotes that a subcarrier is assigned to only one link in a subframe. Problem (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. An applicable resource allocation method is proposed in the next section.

Dynamic Resource Allocation Method

In order to assure an appropriate solution of problem (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 paper.

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

$$\overline{\alpha}_k^2 = \frac{1}{N}\sum_{n=1}^{N} \alpha_{k,n}^2 \quad (7)$$

In (7), 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 $\overline{c}_m$ with $\overline{c}_m \in R^+$. In order to identify S_1, each subcarrier is assumed to carry $\overline{c}_m$ 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

$$B_m = S_m \sum_{k\in K_m} R_k^{(m)} \quad (8)$$

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

$$\overline{c}_m = \frac{B_m}{NS_m} \quad (9)$$

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

$$S_1 \geq \lceil \frac{B_1}{N\max\{D\}} \rceil \tag{10}$$

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 eqn $S_2 = S - S_1$. 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.,

$$S_1 \leq S - \lceil \frac{B_2}{N\max\{D\}} \rceil \tag{11}$$

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

$$\overline{P}_m = \sum_{k \in K_m} \frac{R_k}{\sum_{l \in K_m} R_l} \frac{N f_k(\bar{c}_m)}{\bar{\alpha}_k^2} \tag{12}$$

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 $(S_1^*; S_2^*)$ is chosen which fulfills

$$(S_1^*;\ S_2^*) = \arg\min_{S_1,S_2} \max\{\overline{P_1}, \overline{P_2}\} \tag{13}$$

Subcarrier, Bit and Power Allocation

By considering the eqn (13), 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 (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 [27]. In this approach, this problem is solved in a scenario of a relay network. Keeping the constraints (6b) and (6c), the power used in a subframe is minimized given by

$$P_{min}^{(m)} = \min_{u_{k,n,c}^{(m)}} \sum_{k \in K_m} \sum_{n=1}^{N} \sum_{c \in D} \frac{f_k(c)}{\alpha_{k,n}^2} u_{k,nc}^{(m)} \tag{14a}$$

Subject to:

$$\sum_{n=1}^{N} \sum_{c \in D} c u_{k,nc}^{(m)} \geq R_k^{(m)};\ \forall k \in K_m \tag{14b}$$

$$\sum_{k\in K_m}\sum_{c\in D} u_{k,nc}^{(m)} = 1;\ \forall n \tag{14c}$$

Different to problem (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.

Comparative Analysis

In order to evaluate the performance, this paper employs ACO and ABC algorithm to solve the optimization problem and search for optimal set of optimal subcarrier, bit and power allocation per subframe.

ACO based Optimization Algorithm for Power Reduction

Ant Colony Algorithm is a probabilistic approach for solving computational problems [28]. This approach can be applied irrespective of the objective function complexity in most of the scenarios, making it useful for functions that are highly nonlinear. ACO algorithm focuses to search for an optimal path depending on the behavior of ants looking for a path between colony and food.

When ants find the food they return to their colony though depositing pheromone substance. Thus, based on the pheromone level, the other ants can reach the food by following the “shortest” paths which is marked with strongest pheromone quantities. An Ant tends to select a path positively correlated to the pheromone intensity of founded trails.

The discrete algorithm is a useful meta-heuristic for the travelling salesman problem depending on this biological metaphor. It links an amount of pheromone $\tau(i,j)$ with the connection between two cities. Each ant is located on a random start city and constructs a solution going from city to city, until it has visited all cities. The probability that an ant k in a city i choose to go to a city j is given by equation (15) [29]:

$$P_{ij}^{k} = \begin{cases} \dfrac{\tau_{ij}[(t)]^{\alpha}[\eta_{ij}(t)]^{\beta}}{\sum_{p\in \text{allowed}\,k(t)}[\tau_{ip}\,(t)]^{\alpha}[\eta_{ip}(t)]^{\beta}} & \text{if } j \in \text{allowed } k(t) \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

In this equation, $\tau_{(i,j)}$ is the pheromone between i and j and $\eta(i,j)$ is a simple heuristic function and this is the inverse of the cost of the connection between i and j. β describes the relative significance of the heuristic information. Once all ants have constructed a tour, the pheromone trail intensity will be updated. This is done based on the following equations.

$$\tau_{ij}(t+n) = (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij}(t,t+n) \tag{16}$$

The left segment of the equation makes the pheromone on all edges to decay where as the right part of the equation increases the pheromone level on all edges visited by all ants. The amount of pheromone an ant k deposits on an edge is defined by:

$$\Delta\tau_{ij}^{k}(t+n) = \begin{cases} \frac{Q}{L_k} & \text{if ant k uses edge (i, j)in its tour} \\ 0 & \text{otherwise} \end{cases} \quad (17)$$

L_k is the length of a tour created by ant k. Similarly, the increase of pheromone of an edge is based on the number of ants that use this edge.

The power system optimization problems are dealt with discrete ant colony optimization in [30, 31]. Problem addressed in this paper is unique due to possible load shedding requirement and the output being a binary value.

Modified Ant Colony Optimization:

The discrete algorithm is mainly utilized for ordering problems such as traveling salesman problem, quadratic assignment problem etc. However, the subset problems are fairly different from ordering problems. It is essential to choose the best subset out of the whole set, probably fulfilling certain additional constraints. There is no perception of path here, so it is tough to apply the ideas of discrete ant colony algorithm. For the ordering problems, solution is fixed length, as it is necessary to search for a permutation of a known number of elements. Solutions for subset problems do not have a fixed length. Therefore, it is essential to create a number, Nmax, which will be used to obtain the end of construction cycle for all the ants [32]. The procedural steps are given below:

- The intensity of a pheromone trail on item i at time $t + N_{max}$ is given by following equation, where $N_{max} < n$ is the maximum of items allowed to be added to some solution by some ant.

$$\tau_i(t + N_{max}) = (1 - \rho)\tau_i(t) + \Delta\tau_i^k(t, t + N_{max}) \quad (18)$$

- The increment in the pheromone level in the time $t + N_{max}$ is obtained by summing the contribution of each ant. In the following equation, G is based on the problem and gives the amount of trail being added to item i. Generally, $G(L_k) = Q/L_k$ or $G(L_k) = QL_k$ for minimization or maximization problems and Q is a parameter of the method. L_k is the objective or fitness function found by kth ant.

$$\Delta\tau_i(t, t + N_{max}) = \sum_{i=1}^{n} \Delta\tau_i^k(t, t + N_{max}) \quad (19)$$

$$\Delta\tau_i^k(t, t + N_{max}) = \begin{cases} G(L_k) & \textit{if ant k incorporates} \text{ item } i \\ 0 & \textit{otherwise} \end{cases} \quad (20)$$

- The possibility of choosing a specific item ip as the next item is given by following equation, in which allowed $k(t)$ is the set of remaining feasible items. Therefore, with the higher values of τ_{ip} and η_{ip} , it is more gainful to include item ip in the partial solution.

$$P_{ip}^{k}(t) = \begin{cases} \frac{\tau_{ip}[(t)]^{\alpha}[\eta_{ip}(t)]^{\beta}}{\sum_{ip \in allowed\ k(t)}[\tau_{j}(t)]^{\alpha}[\eta_{j}(t)]^{\beta}} & \text{if ip} \in \text{allowed k(t)} \\ 0 & \text{otherwise} \end{cases} \quad (21)$$

In this approach, two types of heuristics namely static and dynamic heuristics are considered. Static: It is set at the beginning of run to a fixed value. Dynamic: It is based on the partial solution [29].

The subset-based and ordering-based approaches have several features in common. But, in the ordering based algorithms, the pheromone is deposited on the paths where as for subset based algorithms; no path exists connecting the items. The main idea of the ordering problem is that "the more amount of pheromone on a specific path, the more beneficial is that path" [30]. This idea is adapted in the following way in this approach, "the more pheromone trail on a specific item, the more beneficial that item is". Thus, the pheromone is moved from paths to items. Subsequently, a local heuristic is also used in this new version, taking into account items only instead of connections between them.

Problems in ACO

In ACO [31], the tracking depends on the pheromone values at each node, the values of them must be updated regularly to keep its current level as a result of its evaporation. This updating process presents substantial overhead in the optimization process. The final optimal solution can be obtained by examining all of the solution candidates generated by ant exploration. Since, the process is a sequential one in which the solution selection is done only at the end, leads to computational overhead and memory limit problems. Suppose a group of ten ants have been deployed for the optimal solution generation, and if this group of ants fails, then a new group of ten other ants have to be deployed. The time spent for the initial process will be a mere waste and leads to substantial time overhead.

ABC based Optimization Algorithm for Power Reduction

A modeling of artificial bee colony system is seen in figure 1. 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.

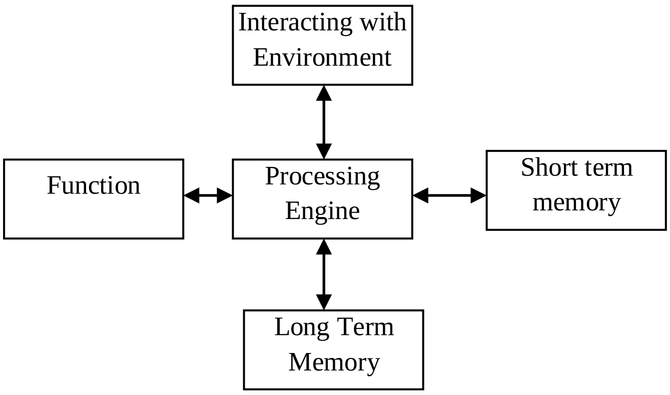

Figure 1: Architecture of Artificial Bees' Colony System

The major steps of the algorithm are as below:
1) Initialization
2) Repeat
3) Place the employed bees on their food sources
4) Calculate the probability values
5) Place the onlooker bees on the food sources
6) Send the scouts to the search area for discovering new food sources
7) Memorize the best food source found so far
8) until a termination is satisfied, and output the best food source found so far

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 gather 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 [33]. 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 Figure 2 [33].

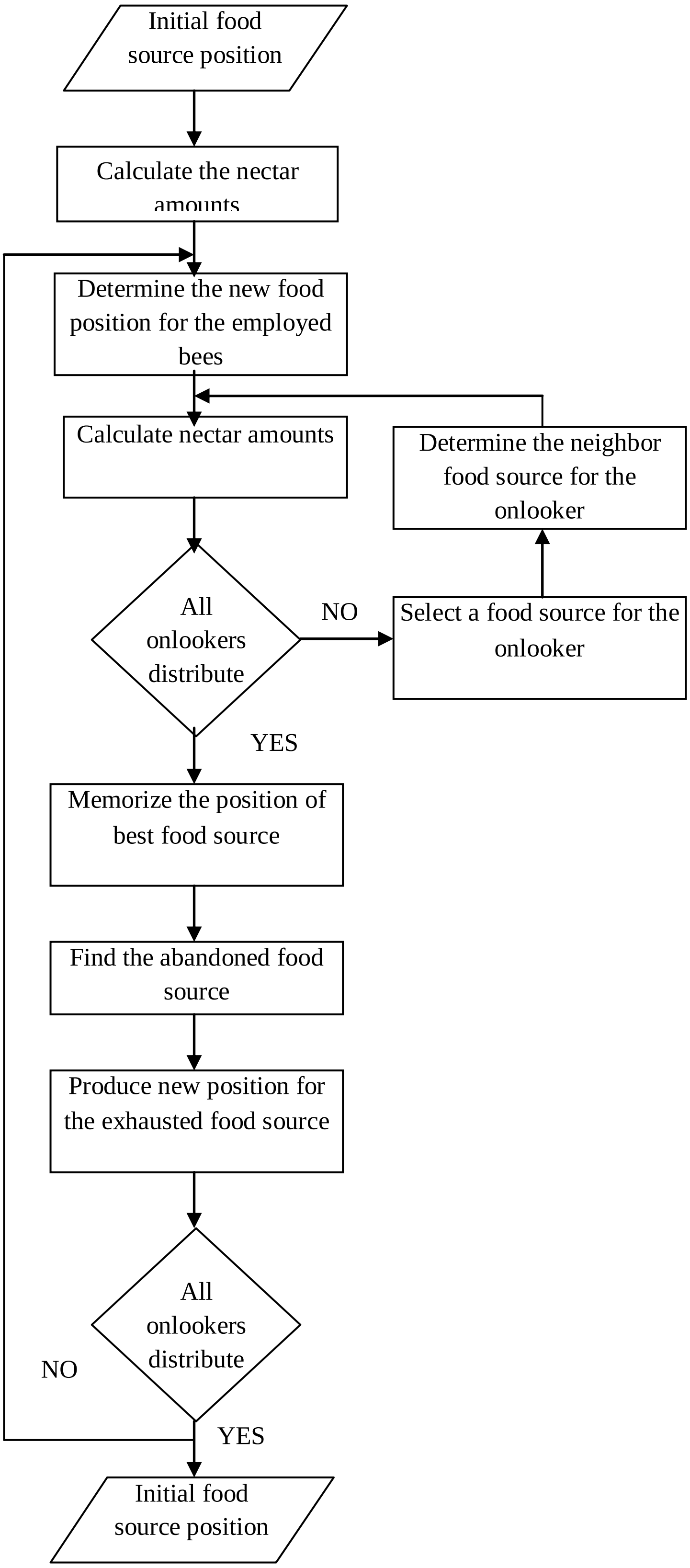

Figure 2: Work Flow of ABC algorithm

In the initial step of ABC, random solutions are generated in the particular range of the variables x_i $(i = 1, \ldots\ldots, S)$. In the next step, novel sources are determined by each employed bee whose total is equivalent to half of the total sources. Equation (22) determines a new source.

$$V_{ij} = x_{ij} + \varphi_{ij}(x_{ij} - x_{kj}) \tag{22}$$

In Equation 22, 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 Equation 23 [33].

$$P_i = \frac{fit_i}{\sum_{j=1}^{SN} fitj} \tag{23}$$

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 [34]. 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 (24) is used to discover a new source of a scout bee [33].

$$xij = xj^{min} + \left(xj^{max} - xj^{min}\right) * rand \tag{24}$$

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 $F(\theta_i)$, where $\theta_i \in R^p$ is done in the maximization problem. θ_i denote the position of the ith source, in which $F(\theta_i)$ represent the nectar amount in this source and it is proportional with $E(\theta_i)$. $P(c) = \{\theta_i(c) | i = 1,2, \ldots . S\}$ 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 $F(\theta)$. 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 [33]:

$$P_i = \frac{F(\theta_i)}{\sum_{k=1}^{S} F(\theta_k)} \tag{25}$$

After the onlooker bee examines the dance of the employed bees and chooses the source with the equality (equation (25)), it discovers a neighboring source and takes its nectar. The location information of the selected neighbor is calculated by the following equation [33]:

$$(c+1) = \theta_i(c) \pm \phi(c) \tag{26}$$

$\phi(c)$ is assessed by considering the difference of certain parts of $\theta_i(c)$ and $\theta_k(c)$, in which k represents different from i, are randomly formed indices of a solution in the population. If the nectar amount of $\theta_i(c+1)$, $F(\theta_i\ (c+1))$, is greater than the nectar amount in the position $\theta_i(c)$, then the bee goes to its beehive and shares this information with the other bees and stays $\theta_i(c+1)$ in the mind as a new position. Otherwise, it keeps $\theta_i(c)$ in mind. If the nectar source of the position θ_i 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 mind denote the possible values of the variables. The solution of the object function is denoted by the attained nectar amount [33].

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 and Discussion

The performance of both the approaches is compared in terms of Cumulative Distribution Function (CDF), bit error rate, convergence behaviour and delay rate. The resource allocation approach through modified subset based ACO and ABC is evaluated 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 [35]. The parameters chosen for the evaluation are given in Table I.

Table 1: Parameters used for the Evaluation

Parameter	Value
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

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 in [36].

Cumulative Distribution Function (CDF)

The channels between BS and SS and RS and SS are modeled by a non-line of sight scenario called C2 and defined in [36]. 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 (27). A bit error probability Pe,c maximally tolerated on a connection is given. For a two hop connection, the maximally tolerated bit error probability is well approximated [37] by the following equation.

$$\mathrm{P_{e,c}} = 1 - (1 - \mathrm{P_e}) \quad (27)$$

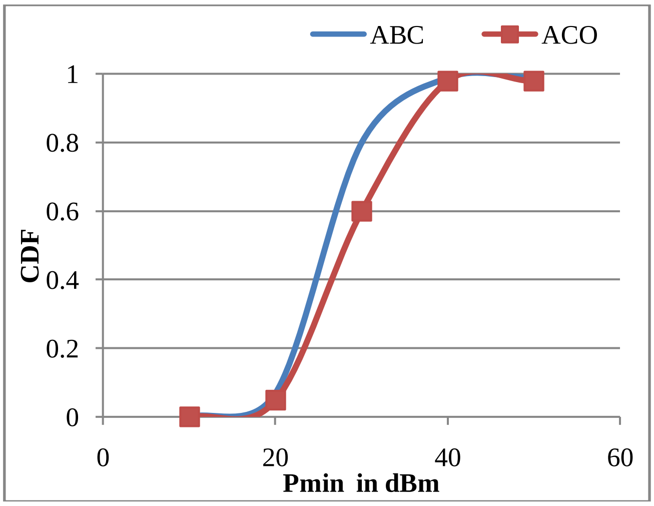

Figure 3: CDF of the maximum out of the transmit powers of the BS

In Figure 3, 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 ACO based OFDM relay is lesser than the other approaches taken for comparison.

Bit Error Rate

Figure 4 shows an example on the difference in coded bit error rate between ACO and ABC. The simulations are performed for a wireless 1024 subcarrier OFDM system with a 50-sample cyclic prefix.

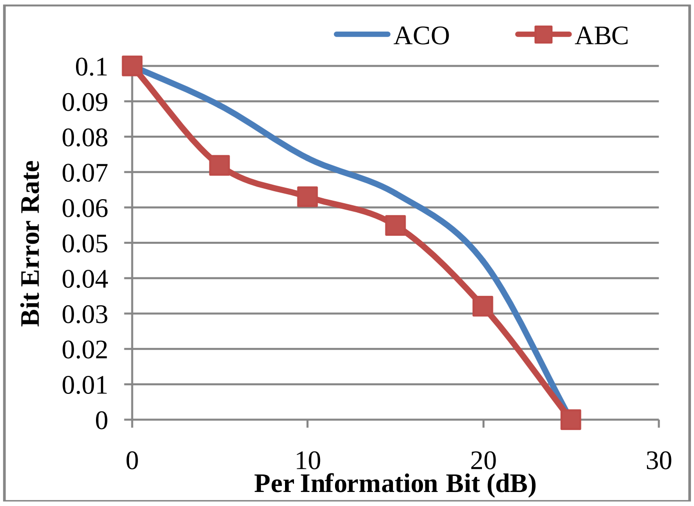

Figure 4: Comparison of Bit Error Rate

It is observed from the figure 5 that the ABC approach provides less bit error when compared with the ACO.

Convergence Behaviour

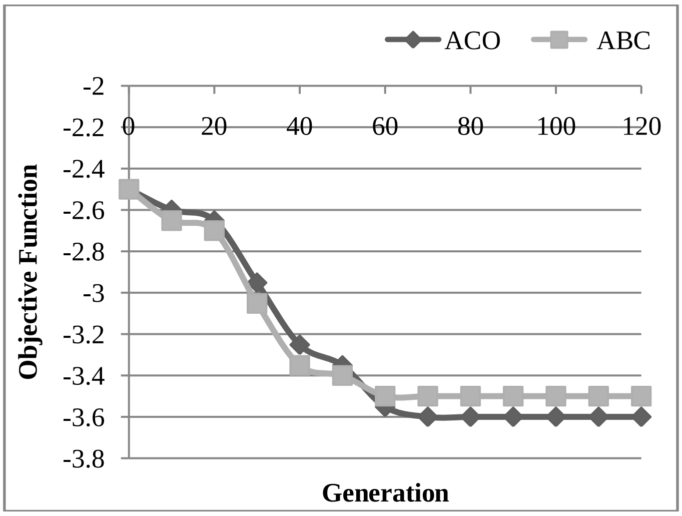

Figure 5: Comparison of Objective Function of the Optimized Technique

It is observed from the figure 5 that the ABC approach provides better convergence when compared with the ACO. The ABC approach takes 60 iterations for convergence where as the ACO takes 70 iterations. Thus, ABC provides better convergence performance.

Delay Rate

Figure 6 shows the comparison of delay rate against the CDF for ACO and ABC.

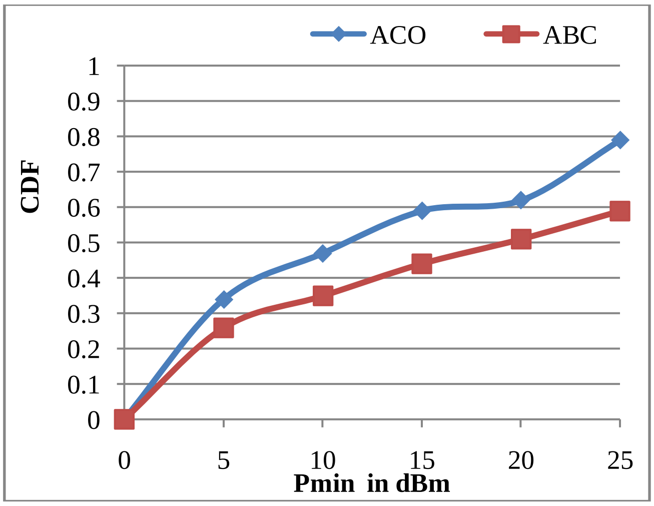

Figure 6: Comparison of Bit Error Rate

It is observed from the figure 6 that the ABC approach provides less delay when compared with the ACO.

Discussion

It is observed from the experimental results that the proposed ABC approach outperforms the ACO approach in terms of Cumulative Distribution Function (CDF), Bit error rate, convergence behavior and delay rate.

The main reasons for the better performance of ABC over ACO are discussed below.

Since, ABC is a Non-Pheromone based technique; there is no need for the updating of pheromone values. The communication between the bees is by means of waggle dance; that is done by setting a status flag for each bee. Parallel behavior of group of bees (multi-threading) makes the algorithm faster in reaching near global optimal solution. The final optimal solution is the improvement done during each iteration of the bees' exploration process. There is no need to examine all the solution candidates generated from the beginning to the end at the final step. Hence, computational overhead and memory limit problems are balanced. If there is no improvement in the current solution, then the scout will start a new search and a new set of test cases are generated. There is no need to deploy more bees for this case. Hence, time overhead is reduced.

Conclusion

In this paper, OFDMA based resource allocation with relays has been analyzed as OFDMA has been considered as the most suitable air-interface technique for the ever-growing wireless access networks and standards. This paper focuses on the process of assigning subcarriers, bits and power dynamically in an OFDMA based relay network such that the power of the BS and the RSs in a cell is reduced.

This paper focuses on identifying the best optimal technique for resource allocation from the field of swarm intelligence. This paper provides a comparative study of two of the most popular optimization techniques namely ACO and ABC.

This paper clearly describes about the drawbacks of the ACO and the reasons for considering ABC for the resource allocation. The main reasons

Subset based ABC is presented in this paper to optimize the subcarriers, bits and power allocation. Based on an efficient ABC algorithm without relay stations, a dynamic subcarrier, bit and power allocation is presented for a relay network. 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 optimization based approach is observed to be better than the other existing approaches. The future work of this approach would be to utilize advanced optimization techniques.

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