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A Dynamic Subcarrier, Bit and Power Allocation for OFDMA-Based Relay Networks Using Swarm Intelligence Based Optimized Approaches-A Comparative Analysis

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Abstract: Orthogonal Frequency-Division Multiplexing (OFDM) is turning out to be an active and promising domain for the future generation of wireless systems owing to its intrinsic 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 study, comparative analysis is carried out by comparing the performance of the two optimization techniques namely, Ant Colony Optimization (ACO), Artificial Bee Colony (ABC) and Improved Artificial Bee Colony (IABC). 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 IABC performs better than the ACO and ABC.

Key words: OFDM, Base station, relay stations, Artificial Bee Colony (ABC), Ant Colony Optimization (ACO), IABC

INTRODUCTION

Conventional Network (CNT) and Relay Network (RNT) are the two significant network structures of wireless cellular networks. In CNT, SS is directly connected 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 next proficient kind of a future network where additionally to BSs and SSs, Relay Stations (RS) also exists (Muller *et al*., 2007). 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) in addition to the entire 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*., 2007).

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 (Akyildiz *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, 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*., 2012).

The amalgamation of OFDMA technology and the relay network structure provides a hopeful platform which offers good flexibility in terms of resource allocation, such as subcarrier allocation, scheduling and power control to attain the multi-dimensional diversity gain (Hua *et al*., 2010; Thanabalasingham, 2006).

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 Letaif, 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. 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.

In this study, comparative analysis is carried out by comparing the performance of the three optimization techniques namely, Ant Colony Optimization (ACO), Artificial Bee Colony (ABC) and Improved Artificial Bee Colony (IABC).

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 (14). Each user is able to be assigned to 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 fields which comprises of digital audio/video broadcasting (16) and wireless LANs (17). It has also been considered as the access technique for future systems such as WiMAX (18).

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.

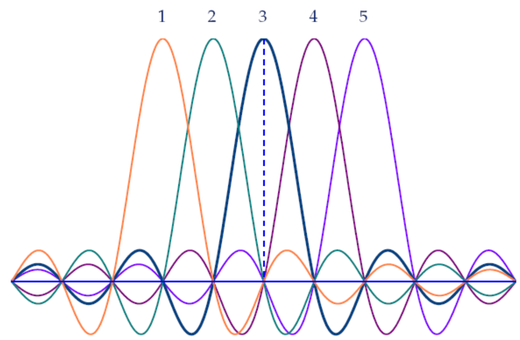

Fig. 1: Example of an OFDM signal spectra: the spectrum of every one subcarrier has a null at the center frequency of each of the others

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.

Literature survey: Several researchers have proposed various techniques on resource management. This study 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 by Tassiulas and Ephermides (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; 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 heterogeneous traffic flows within the system's capacity region. Thus, a congestion control method is presented by Eryilmaz and Srikaut (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 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*. (2010) 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.

Comparative analysis: The formation of resource allocation problems are as follows.

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 (Muller *et al*., 2007). An index k = 1, 2...,K i 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. The links between all RSs and the SSs are in the set. 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 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 slots with index 1 to. 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, the RSs transmit from slot +1 until slot S. The subframe index is represented by m, i.e.. 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 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 of QPSK and QAM depending on the signal to noise ratio (Proakis, 1995), the function $f_k(c)$ is given by:

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

Where:

$Q_{-1}(.)$ = Represents the inverse complementary error function

The function $f_k(c)$ = Monotonically increasing with $f_k(0) = .0$

The transmit power needed on a subcarrier is given by:

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

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 $\alpha_{k,n,c}^{(m)}$ is defined as:

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

The transmit power used in subframe m is given by:

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

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 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:

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

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

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

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. Equation 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 Eq. 6, the problem is split into the following subproblems: Initially, the subframe sizes and 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 used. For this, an algorithm described for a network without RSs is personalized to a relay network. For this operation, an efficient optimization technique is adapted in this study.

Subframe size: The subframe sizes and must be obtained with no significant of 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. On behalf of all potential sizes of the subframes, the maximum of the transmit power of the BS and of the RSs is calculated. 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:

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

In Eq. 9, the arithmetic mean value is selected be in each channel has an equal weight as no acquaintance of the subcarrier allocation is given. The representative number of bits per subcarrier is $\overline{C_m}$ with $\overline{C_m} \varepsilon R^+$. 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:

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

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:

(•)	=	Represents the rounding to the next greater integer value and
max{D}	=	The greatest element of the set D. The size S_2 is given by the Eq. $S_2 = S\text{-}S_1$
The size S_1	=	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:

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

An arithmetic mean value is chosen in which each power is weighted by its normalized requested data rate as it is unspoken that the higher the data rate of a link the more subcarriers are allocated to that link. Out of all possible combinations of S and S_2, the combination (S_1*; S_2*) is chosen which fulfills:

$$\left(S_1^*;S_2^*\right) = \text{argmin}_{S_1,S_2} \max\left\{\bar{P}_1, \bar{P}_2\right\} \quad (15)$$

Subcarrier, bit and power allocation: By considering the Eq. 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 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 8, the power used in a subframe is minimized given by:

$$P_{min}^{(m)} = \min_{u_{k,n,c}^{(m)}} \sum_{k \varepsilon K_m} \sum_{n=1}^{N} \sum_{c \varepsilon D} \frac{f_k(c)}{\alpha_{k,n}^2} u_{k,n,c}^{(m)} \quad (16)$$

$$\sum_{n=1}^{N} \sum_{c \varepsilon D} c u_{k,n,c}^{(m)} \geq R_k^{(m)}; \forall k \varepsilon K_m \quad (17)$$

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

Different to 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.

MATERIALS AND METHODS

Proposed approach for dynamic subcarrier, bit and power allocation in ofdma-based relay networks: In order to evaluate the performance, this study employs ACO, ABC and IABC 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 Eq. 18. 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 has a propensity 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 τ (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 Eq. 19 and 29:

$$P_{ij}^{k} = \begin{cases} \dfrac{\tau_{ij}\left[(t)\right]^{\alpha}\left[\eta_{ij}(t)\right]^{\beta}}{\sum p\varepsilon allowedk(t)\left[\tau_{ip}(t)\right]^{\alpha}\left[\eta_{ij}(t)\right]^{\beta}} & \text{if } j \in allowedk(t) \\ 0 & \text{otherwise} \end{cases} \quad (19)$$

In this Eq. τ (I, j) is the pheromone between i and j and η (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. On one occasion all ants have built a tour, the pheromone trail intensity will be updated. This is done based on the following Eq.:

$$\tau_{ij}(t+n) = (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij}(t, t+n) \quad (20)$$

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 quantity of pheromone in which the ant k dump on an edge is defined by:

$$\Delta\tau_{ij}^{k}(t+n) = \begin{cases} \dfrac{Q}{L_k} & \text{if ant k uses edge}(i, j) \text{in its tour} \\ 0 & \text{otherwise} \end{cases} \quad (21)$$

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 (Hamdaoui *et al*., 2005).

Modified ant colony optimization: The discrete algorithm is primarily 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, N_{max} which will be used to obtain the end of construction cycle for all the ants. The procedural steps are given as follows.

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:

$$\tau_i(t+N_{max}) = (1-\rho)\tau_{ij}(t) + \Delta\tau_i^k(t, t+N_{max}) \quad (22)$$

The increment in the pheromone level in the time $t+N_{max}$ is attained by adding 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 $G(L_k)$ 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:

$$\Delta\tau_i(t, t+N_{max}) = \sum_{i=1}^{n}\Delta\tau_i^k(t, t+N_{max}) \quad (23)$$

$$\Delta\tau_{ij}^{k}(t, t+N_{max}) = \begin{cases} G(L_k) & \text{if ant k incorporates item i} \\ 0 & \text{otherwise} \end{cases} \quad (24)$$

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:

$$P_{ip}^{k} = \begin{cases} \dfrac{\tau_{ip}\left[(t)\right]^{\alpha}\left[\eta_{ip}(t)\right]^{\beta}}{\sum ip \in allowedk(t)\left[\tau_j(t)\right]^{\alpha}\left[\eta_j(t)\right]^{\beta}} & \text{if } ip\varepsilon allowedk(t) \\ 0 & \text{otherwise} \end{cases} \quad (25)$$

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.

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". 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, 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

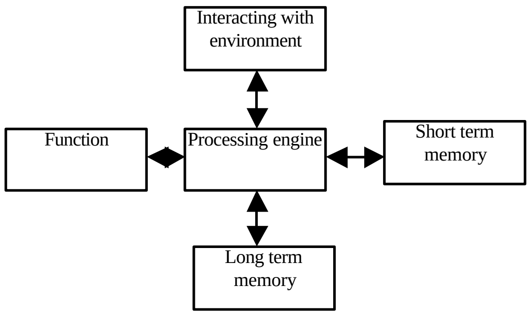

Fig. 2: Architecture of artificial bees' colony system

ultimate optimal solution can be obtained by investigating all 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 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 below:

- 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

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 (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.

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 26 determines a new source:

$$V_{ij} = x_{ij} + \varphi_{ij}\left(x_{ij} + x_{ij}\right) \tag{26}$$

In Eq. 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 Eq. 27 (Ravi and Duraiswamy, 2011):

$$P_1 = \frac{fit_i}{\sum_{j=1}^{SN} fitj} \tag{27}$$

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 Senthilnath, 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 24 is used to discover a new source of a scout bee (Ravi and Duraiswamy, 2011):

$$xij = xj^{min} + \left(xj^{max} - xj^{min}\right) * rand \tag{28}$$

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

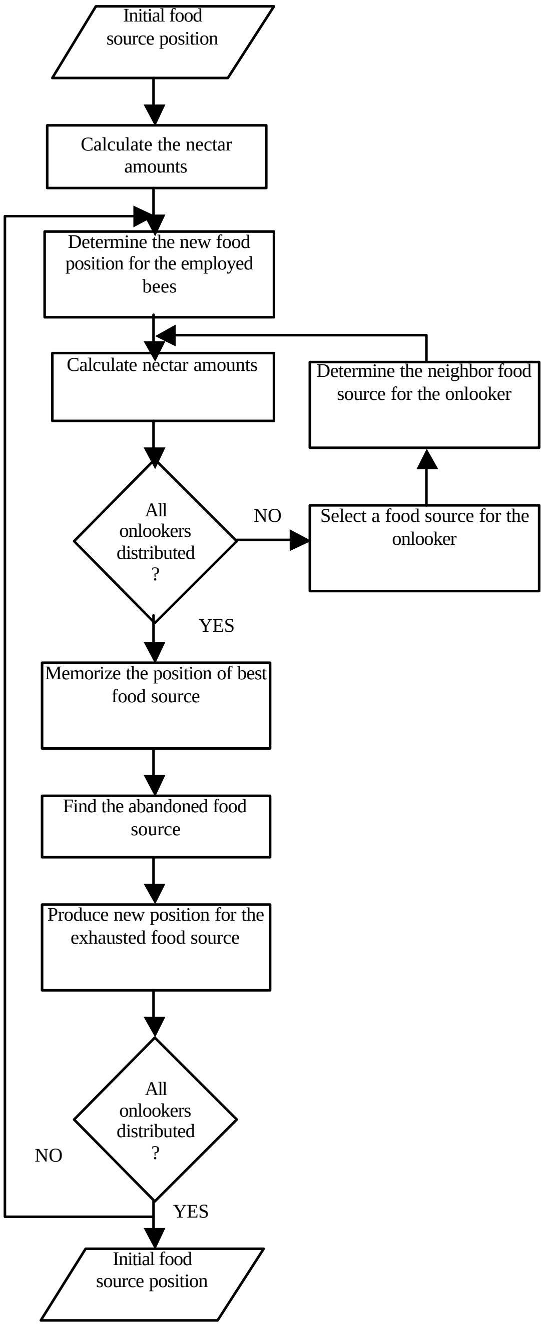

Fig. 3: Work flow of ABC algorithm

the quantity of the foods that are brought to the nest. The maximization of the objective function is $F(\theta_i)$ where $\theta_i \epsilon R^p$ is done in the maximization problem. denote the position of the ith source, in which $F(\theta_i)$ represent the nectar amount in this source and it is proportional with $E(\theta_i)$. $P(c) = \{\theta_i(c)| = 1, 2 ...S\}$ 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 $F(\theta)$. 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 (Ravi and Duraiswamy, 2011):

$$P_1 = \frac{F(\theta_i)}{\sum_{k=1}^{S} F(\theta_k)} \tag{29}$$

After the onlooker bee examines the dance of the employed bees and chooses the source with the equality Eq. 25, 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):

$$(c+1) = \theta_i(c) \pm \phi(c) \tag{30}$$

The $\phi(c)$ 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, $\theta_i(c+1)$, $F(\theta_i(c)$ 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 $\theta_i(c)$ 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 (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.

Proposed modified artificial bee algorithms for power stabilization: The basic ABC algorithm is a simple, robust and effortlessly controlled algorithm. However as a random optimization algorithm, ABC algorithm has slow convergence features and easily gets stuck on local solutions. In this study, the basic ABC algorithm is modified to obtain improved optimization value.

Improved ABC 1 (IABC1): In the basic ABC algorithm, greedy selection is applied between the current solutions and the new solutions, the new solutions are produced from the parent solutions as Eq. 19, the new solution V_i is obtained only altering one parameter of the parent solution x_i and this result in a slow convergence rate. To this point x_i and x_{i-1} is combined to obtain the new solution V_i as:

$$\begin{aligned} V_{ij} &= x_{ij} + r_{ij}\left(x_{ij} - x_{kj}\right), i = 1 \\ V_{ij} &= x_{i-1j} + r_{ij}\left(x_{ij} - x_{kj}\right), i > 1 \end{aligned} \tag{31}$$

Where $X_{1\text{-}1j}$ denotes the former neighbor of and the better one selected by greedy selection. Thus, the search range is higher than in the fundamental ABC algorithm and the convergence rate is enhanced. Equation 21 is only applied in the exploration of employed bees and onlooker bees still apply Eq. 19 to keeping the local searching. The integration of the global exploration and local search obtains to better balance avoiding the optimization to be got into the local best value.

Improved ABC 2(IABC2): In the fundamental ABC algorithm, a random real number within the range [0, 1] is produced for each source. If the probability value (prob (i) in Eq. 20 associated with that source is higher than this random number then the onlooker bee generates a new solution by using Eq. 15. As the random number is stochastic, certain good solutions are predictable to be skipped. The sensibility replace of the random number is used. The sensibility was proposed in free search algorithm by Penev in 2005 (Su *et al*., 2005), it is described as:

$$S_i = S_{min} + r_i\left(S_{max} - S_{min}\right) \tag{32}$$

Where S_i denotes the sensibility of the ith solution, r_i represents a uniformly distributed real random number in the range (-1, 1) S_{max} and S_{min} are minimal and maximal possible values of the sensibility where S_{max} = $prob_{max}$ and S_{min} = S_{min} = $prob_{min}$ If (i)>S_i then the onlooker bee can generate a new solution and choose the food source by greedy selection.

Improved ABC (IABC): IABC1 and IABC2 are integrated in which the employed bees search the new food source by Eq. 17 and the onlooker bees constructs a new solution if the probability is greater than the sensibility of the present solution.

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

RESULTS AND DISCUSSION

The proposed resource allocation approach through 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. The parameters chosen for the evaluation are given 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 in (Ravi and Duraiswamy, 2011).

The channels between BS and SS and RS and SS are modeled by a non-line of sight scenario called C2 and defined in (Ravi and Duraiswamy, 2011). 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 Pe,c maximally tolerated on a connection is given. For a two hop connection, the maximally tolerated bit error probability is well approximated (Omkar and Senthýlnath, 2009) by the following Eq. 33:

$$P_{e,c} = 1 - \left(1 - p_e\right) \tag{33}$$

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

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

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

approach solves the Eq. 6 by testing all possible combinations of the subframe sizes S1 and S2. For all combinations, the Eq. 14 is handled by a suboptimal approach as in (Su *et al*., 2005) and is not optimally solved to minimize complexity. The near optimum technique is a close approximation to the optimal solution of Eq. 6 as the difference between the optimal solution of Eq. 14 and its suboptimal solution is less than 0.25 dB in the analysis of (Su *et al*., 2005).

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.

Cumulative Distribution Functions (CDFs) of the maximum out of the transmit powers of the BS and the sum of the powers of the RSs is clearly shown in figure 4. The connections of eight SSs are considered within a frame. It is observed from Fig. 4 that the median of the proposed IABC based OFDM relay is lesser than the other approaches such as Near optimum, OFDM relay, fixed subframe size, static, ACO based approach, ABC based approach and IABC based approach.

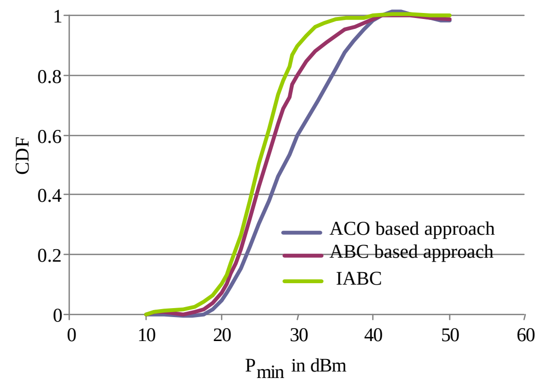

Fig. 4: CDF of the maximum out of the transmit powers of the BS

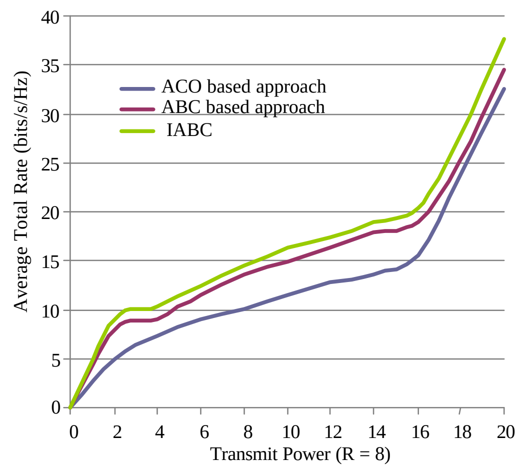

Fig. 5: Average total capacity for different SNR

Average total capacity and transmit power: In Fig. 5, the performance of the proposed approaches is compared with the existing approaches in terms of average total data rate. From Fig 5, it is observed that with the increment of transmit power, the performance of the proposed IABC approach provides better results than the other approaches. The total data rate is found to increase with higher transmit powers.

Average total capacity for different relay number k: Figure 6 illustrates the data rate with different number of relay nodes. In this experiment, the date rates of the algorithms are compared. The data rate increases with increase in the number of relay nodes. However, the slope of the curves become small when the user number is large which indicates that the incremental gains from the additional relay nodes will be diminished as the number of the relay nodes grow.

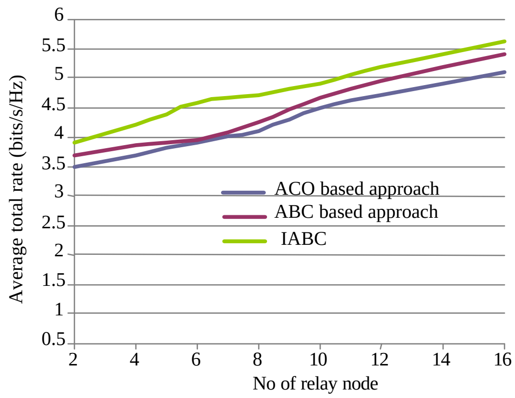

Fig. 6: Average total capacity for different relay number K

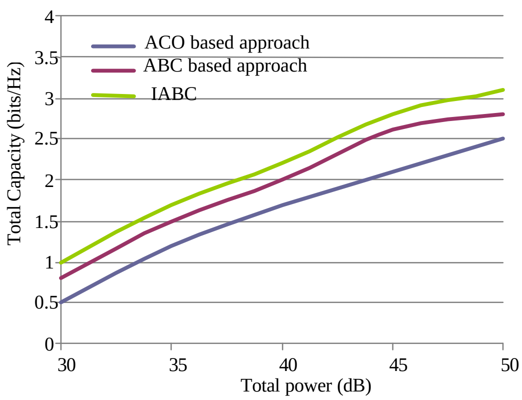

Fig. 7: Total power vs. total capacity, K = 6

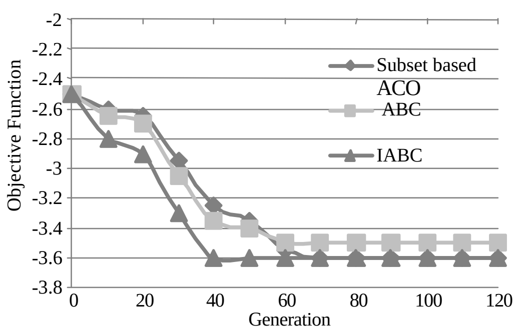

Fig. 8: Comparison of objective function of the optimized technique

The proposed IGSESABC approach provides an average total rate of 5.6 bits/s/Hz when the number of relay node is 16. However, the proposed ABC and ACO approaches attain an average total rate of 5.4 and 5.1 bits/s/Hz, respectively.

The existing approaches attain an average total rate lesser than the proposed approaches. Thus, it is clearly observed that the proposed IGSESABC approach outperforms the other approaches.

Total power vs. Total capacity: Figure 7 shows the comparison of performance of the proposed approaches with the existing approaches. The system performance is greatly improved since subcarriers are not distributed to the relay with bad channel gain. It is observed that with higher transmit power, the performance of the proposed schemes becomes more significant and the total throughput increases more quickly.

The proposed IGSESABC approach outperforms the other approaches. For a total power of 50 dB, the total capacity obtained by the proposed IGSESABC approach is 3.1 bits per Hz. The other approaches are observed to produce lesser total capacity when compared with the IGSESABC. Thus, IGSESABC attains higher total capacity for all the considered power.

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 Fig. 8 that the proposed subset IABC approach provides better convergence when compared with the linear programming approach, ACO approach and ABC approach. The proposed IABC approach takes 40 iterations for convergence where as the linear programming approach takes 90 iterations for convergence. ACO and ABC take 70 and 60 iterations for convergence respectively. Thus, IABC provides better convergence performance.

CONCLUSION

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

This study focused on the process of allocating subcarriers, bits and power dynamically in an OFDMA based relay network in order to reduce the power of the BS and the RSs in a cell. An improved artificial bee colony optimization technique is presented for an appropriate resource allocation technique taking into consideration a requested data rate and that a RS cannot transmit and receive at the same time. IABC optimizes 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 IABC optimization based power allocation approach for OFDM based relay network is observed to be better than other existing power allocation approaches taken into consideration.

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