Solving Interference Problem with Multi-Objective Evolutionary Optimization

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Abstract:-Interference is crucial problem for wireless networks that may disable them. In this paper, an optimization approach to solve interference problem is represented. Communication ways in network have different properties, so Multi-Objective Competitive Algorithm is used for this problem. MOICA is new algorithm to solve multi-objective optimization problems.

Key-words:- Multi-objective Optimization; graph theory; Imperialist Competitive Algorithm.

1 Introduction

Nowadays, wireless communication is very popular and we can mention many of applications of it. Unfortunately, wireless communication sufferers from critical aspect named as Interference. Interference is a coherent emission having a relatively narrow spectral content. Informally, node *u* may interfere with node *v* if *u*'s interference range covers *v*. minimizing interference may help in lowering node energy dissipation by reducing the number of collisions and consequently retransmission on the media access layer. There are number methods to reduce interference. One of them is frequency allocation [4]. The main subject of this method is assigned a channel to each node. When each node transmit in own channel, the collision is reduced, but a new problem is created and that is finding a proper channel for each node.

Reduction of interference is subject of number papers. In [11], the constrained group decoder is considered. The advantage of this method is lower transmission. Since, there is no need to feedback in this method, traffic of data stream's transmission decreases. This way needs to employs a fixed-rate channel code and modulation scheme. [8] focuses on cellular networks. They proposed a pattern for networks. In their pattern, cells are arranged in either an infinite linear array or in some two-dimensional pattern, with interference originating only from immediate neighboring cells. Their pattern is very far from real world, because determination of position for cells in real world is difficult. In

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[9], different scenarios of interference are represented. In [10], graph coloring is used to reduce interference.

Network can be modeled as a graph $G = (V, E)$. Vertexes, which are shown with *V*, are nodes and edges, which are represented with *E*, are communication channels. To reduce interference in frequency allocation method, we have two targets: 1) assignment a channel to each node subject to no couple adjacent nodes has same channel. This problem can be modeled by Graph Coloring problem. 2) each node has appropriate channel.

There are numbers optimization algorithms and each of them has own feature. Optimization algorithms can be divided into two categories: 1) deterministic and 2) Non-deterministic. Deterministic algorithms do certain stages. In front of them, although non-deterministic algorithms have also number stages, but they go trough stages with random individuals. One important class of non-deterministic algorithms is swarm intelligence.

Swarm intelligence is a set of popular optimization methods which are used in spread area of engineering fields. The reason for attractively of theses methods may be their inspirations. The swarm intelligence methods are inspired from nature. Since mathematic model of natural events works easily, the swarm intelligence methods are against of other optimization methods. The swarm intelligence principle is based on many unsophisticated entities that cooperate in order to exhibit a desired behavior [1]. Another feature which cause the swarm intelligence are popular is their power to exploit. Each model, which is object of optimization algorithm, has numbers optimum points in varied energy levels. A rich optimization algorithm to reach optimum point must traverse various energy levels. The energy levels of a specific optimization problem are represented by its feasible region. Unfortunately, the feasible region may have numbers semi-optimum points, which are optimum in a section of the feasible region, but not entire of it. These semi-optimum points are named as <u>local minima</u> and may confuse the weak optimization algorithms. In words, the weak optimization algorithms may presume local minima as <u>global minima</u> (optimum points in entire feasible region). Since the swarm intelligence methods use numbers entities and each entity works stochastic, the swarm intelligence methods can escape from local minima traps and achieve global minima points.

There are numbers swarm intelligence algorithms and also there are many optimization problems that are solved with SI (swarm intelligence) [1, 2, 3]. Indeed structure of algorithms number of objects is also important. A class of SI algorithms tries to optimize one object (single-objective), despite another class of SI tries to optimize more than one object (multi-objective). Multi-objective optimization algorithms are modified single-objective optimization algorithms for number objects. The ability of each SI algorithms to solve the specific optimization problem is different and can concern in various focuses. One interesting problem is Frequency Allocation. In this research two multi-objective algorithms (multi-objective imperialist competitive algorithm and multi-objective bee colony algorithm) are considered.

The assignment proper channel to network's nodes problem can be solved with Multi-Objective Optimization algorithms. The rest of this paper is organized as follows: section 2 is assign to some preliminaries of graph theory. In section 3, description of problem with details is represented. Section 4, explains multi-objective optimization and one algorithm (multi-objective imperialist competitive algorithm), which is used in this research. Finally in section 5 the result of algorithm is represented.

2 Graph Theory

Graph theory is very usable in computer science, because it has ability to model of many structures. Let $G = (V, E)$ be an undirected simple graph and $V(G), E(G)$ are vertexes and edges of a particular graph *G*. the vertexes *v*,*w* are called <u>adjacent</u> if there is an edge $\{v, w\} \in E$ joining them. The <u>Neighborhood</u> of $x \in V$ is $N(x) = \{y \in v | \{x, y\} \in E\}$ and its <u>closed neighborhood</u> is $N(x) \cup \{x\}$ which is denoted by $N[x]$. The cardinality of a set *A* is denoted by $|A|$. The degree of a vertex $x \in V$ is $\delta(x) = |N(x)|$. The size of the neighborhood of *x* is $\delta(N(x)) = \sum_{y \in N(x)} \delta(y)$. A sub-graph Δ of *G* is called a clique if two distinct nodes in Δ are always adjacent in *G*. a clique with *k* nodes is simply called a *k*-clique. A *k*-clique in *G* is defined to be a maximum clique if *G* does not contain any (*k+1*)-clique. The graph *G* may have several maximum cliques. Each

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maximum clique in G has same number which is called as clique size of G and denoted by $\omega(G)$.

A coloring of a graph is an assignment of colors to its vertexes [5]. Coloring satisfies the following conditions: 1)each node of graph receive exactly one color; 2)adjacent nodes never receive the same color, so they use numbers 1,…,k as colors and the coloring is defined by a map: $f: v \rightarrow \{1, \cdots, k\}$. Therefore, $f(v_1) = f(v_2)$, $v_1 \neq v_2$ implies that v_1 and v_2 are not adjacent. Indeed, edges of that graph is colored and also satisfies two conditions: 1)each edge receive exactly one color; 2)if x,y,u,v are nodes of a 4-clique in graph, then the edge $\{x, y\}$ and $\{u, v\}$ cannot have same color (B type, it is proposed by Bogdan Zavalnij). In other words, if coloring of edges is identified by $g: E \rightarrow \{1, \cdots, k\}$ and we have $g(\{x, y\}) = g(\{u, v\})$, $\{x, y\} \cap \{u, v\} = \emptyset$ implies that x,y,u,v are not nodes of a 4-clique in graph [6]. Chromatic number is smallest number of colors which can color a specific graph and denoted by $\chi(G)$ [7].

3. The Problem

Transmitting nodes influence the ability the other nodes to receive data. A node is not able to receive data from its neighbor if it was interfered by receiving a transmission not intended to it. This mutual disturbance of communication is called interference. Reducing interference in the

network leads to fewer collisions and packet retransmissions, which indirectly reduces the

power consumption and extends the lifetime of the network. Therefore, reducing the interference is an important goal for wireless networks. If a network incurs a large interference, either many communication signals sent by nodes will collide, or the network may experience a serious delay at delivering the data for some nodes, and even consume more energy. So, we reach to the conclusion that the interference is a major drawback of wireless networks. The aim of reducing interference is to prevent adjacent or connected nodes, which are linked by radio signals, from receiving and transmitting signals which conflict or blend together. Numerous methods for reducing interference exist, such as topology control, power control, and channel assignment [4]. The network's nodes must transmit their data stream on proper channel to reduce interference effect [8,9,10, 11, 12, 13].

Let vertexes of graph are $\{A, B, C, D, E, F, G, H\}$ and there are four colors

RED	BLUE	GREEN	YELLOW
1	2	3	4

Table 1. colors and their assigned numbers

The Adjacent Matrix, which has 1 if and only if there is an adjacent relation and is 0 if and only if there is not an adjacent relation, is represented in table 2.

	A	B	C	D	E	F	G	H
A	0	1	1	0	0	1	0	1
B	1	0	0	1	0	0	1	1
C	1	0	0	1	1	0	0	1
D	0	1	1	0	1	0	0	0
E	0	0	1	1	0	1	1	1
F	1	0	0	0	1	0	0	1
G	0	1	0	0	1	0	0	1
H	1	1	1	0	1	1	1	0

Table 2. The Adjacent Matrix

Let this graph is model of network and we use frequency allocation technique to prevent inference effect. According to definition of graph coloring, frequencies which are denoted with colors are allocated to nodes without any collision. Thus, the first object of problem is *finding a mapping between colors and nodes* subject to graph coloring conditions.

Suppose that colors are not free and nodes to receive them must pay amounts of price. Value of colors is represented in table 3. (Unit of prices can not influence on problem)

1	2	3	4
1000	500	750	1300

Table 3. colors and their prices

This assumption causes model near to real world. Since network's nodes in real world pay some costs (such as time, power, value, etc.), colors in model have prices. In this case, each node has specific stock and node can receipts color with its stock. Thus, the second object of problem is *finding the minimum cost of graph coloring* subject to restriction of each node's stock.

4 Multi-Objective Optimization Algorithms

Suppose there is a function with n variables. The goal of optimization is set variables in order to optimum value of function. Optimization algorithms can be divided into two classes according to number of functions: 1)single-objective optimization algorithms. These classes of algorithms are used when there is just one function as target and we want find optimum values for that function. 2)multi-objective optimization algorithms. These classes of algorithms are used when there are more then one algorithm as target.

Most of the problems in the real world are multi-objective and they require multi-objective optimization for better solutions. Multi-objective optimization is defined as [14]:

$$\begin{aligned} &Optimize \quad \{f_1(X), f_2(X), \ldots, f_k(X)\} \\ &subject \quad g_i(X) \le 0,\ h_j(X) = 0 \\ &i = 1, \ldots, m \quad j = 1, \ldots, p \end{aligned} \tag{1}$$

Where k is number of objective functions, X is the decision vector, m is number of inequality constraints and p is number of equality constraints. Many researchers have tried to find an appropriate approach to solve multi-objective problems [14, 15, 16, 17].

Multi-objective optimization is special type of general optimization and characteristic concept of it is *dominance*. Despite of single-objective optimization approaches, which optimum values are wanted, multi-objective optimization algorithms follow non-dominated values.

Formally, a vector $\vec{u} = (u_1, u_2, \cdots, u_k)$ is said to dominance $\vec{v} = (v_1, v_2, \cdots, v_k)$ (denoted by $\vec{u} \preccurlyeq \vec{v}$ if and only if $\vec{u}$ is partially less than $\vec{v}$, i.e. $\forall i \in \{1, \cdots, k\}: u_i \le v_i \ \bigwedge\ \exists i \in \{1, \cdots, k\}: u_i < v_i$. The set of non-dominance values are goal of multi-objective optimization according to <u>Pareto Optimality</u>.

We say that a vector of decision variables $X^* \in \mathcal{F}$ is *Pareto Optimal* if there not exist another $X \in \mathcal{F}$ such that $f_i(X) \le f_i(X^*)$ for all $i = 1, \cdots, k$ and $f_j(X) < f_j(X^*)$ for at least one j [14]. In words, this definition says that X^* is Pareto Optimal if there is not any feasible vector of decision variables $X \in \mathcal{F}$ which would decrease some criterion without causing a simultaneous increase at least one other criterion. Unfortunately, this concept almost always gives not a single solution, but rather than a set of solutions called the Pareto Optimal set. The vector X^* corresponding to the solutions included in the Pareto Optimal set are called *non-dominated*. The image of the Pareto Optimal set under the objective functions is called *Pareto Front*. The concept of Pareto Optimal set in mathematical language is defined as (2).

$$P^* \coloneqq \left\{x \in \mathcal{F} \,\middle|\, \nexists x' \in \mathcal{F}\ \vec{f}(x') \preccurlyeq \vec{f}(x)\right\} \tag{2}$$

In a multi-objective problem and with Pareto Optimal set, the Pareto Front can be defined as follow:

$$PF^* = \left\{\vec{u} = \vec{f} = (f_1(x), f_2(x), \cdots, f_k(x)) \,\middle|\, x \in P^*\right\} \tag{3}$$

Where k is number of objects.

4.1. Multi-Objective Imperialist Competitive Algorithm

Imperialist Competitive Algorithm (ICA) is a new method belonged to swarm optimization class. ICA has extraordinary ability to solve optimization problems. The objective of this paper is research about ability of Multi-Objective Imperialist Competitive Algorithm (MOICA) to solve multi-objective optimization problems.

ICA is inspired socio-political events, so most names which are used in it can be found in real world. MOICA starts with an initial population (random solutions) named *countries* [18, 19, 20]. Each country is an individual of solution. Population is partitioned to *empires*. The number of countries and empires are defined by algorithm implementer and denoted with $N_{country}, N_{empire}$. Same as real world which any country has own fitness; countries of MOICA also have fitness. The cost or fitness of a country represents its *power*. Power of each country is calculated using the value of that country according to an *objective function*, so $cost^i_j$ is power of j^{th} country for i^{th} *objective function*:

$$\begin{aligned} power_j &= \cos^1_j(value_1, \ldots, value_n) + \ldots \\ &+ \cos^i_j(value_1, \ldots, value_n) \end{aligned} \tag{4}$$

In each empire, the country with the highest power is called *imperial*, and all remaining countries are called *colonies*. The total power of the empire is the sum of the powers of all countries in that empire.

Fig. 1, Imperials and colonies

MOICA same as other evolutionary optimization algorithms does some jobs in a loop until the

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termination criterion of the algorithm is satisfied. At each iteration:

- The power of all countries is changed. Colonies move toward their imperial. This movement is simple model of assimilation policy that was perused by imperialist country. Let *d* is distance between imperial and colony. x, θ are random numbers with uniform distribution.

$$x \sim U(0, \beta \times d), \theta \sim (-\gamma, \gamma) \quad (5)$$

β, γ are arbitrary numbers that modify the area that colonies randomly search around the imperial. Power of colonies in empire move with x, θ .

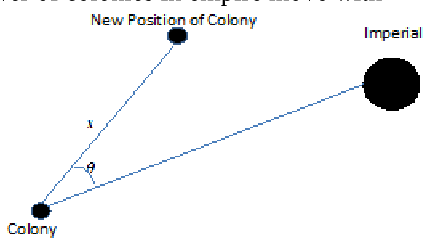

Fig. 2, Movement of colony toward imperial

- The power of countries is reevaluated, thus the imperial of any empire may change if one colony enriches power higher than its imperial and can dominate its imperial, substitute with it. If there are number non-dominate country in empire, one of them is selected randomly and move to special place named as *archive*.
- Each imperialist country absorbs colonies of other empires based on power of its empire. This imperialist competition results in the best collection of countries, which corresponds to a solution for a single-objective problem.

Multi-objective ICA requires keeping the non-dominated solutions in a separate space, which is called *archive*. There are two important points **(i)** algorithm must keep all non-dominated solutions in an archive to preserve from diversity. **(ii)** The algorithm must avoid deterministic methods to discover a large number of non-dominated solutions. Instead of deterministic movements, using random movements helps the algorithm to escape from *local optimum* and increase the chance of reaching the *global optimum*. Therefore it is better to construct the next population randomly from the archive or from the current population by a probabilistic method.

- The algorithm has to decide which country must be kept in archive randomly. All countries are compared with each other (according to (2)) and non-dominated countries are known. If there are *k* non-dominated countries, the summation of powers for non-dominated countries is given by (6).

(6)

All non-dominated countries have probability for entrance to archive and probability for j^{th} country is calculated by (7).

$$prob_j = \frac{power_j}{SumPower}$$

(7)

Countries in archive may have 3 situations related to new country:

- The old countries may dominate new country. In this state, new country being fired.
- New country may dominate all or some of the old counties. In this state, dominated countries get out.
- The old countries and new country are non-dominated. In this case, new country is kept in archive.

5. Experimental Result

In this paper MOICA is used to solve interference problem in wireless network. At first, network is a graph, so problem becomes to graph theory problem. Secondly, MOICA is applied and for using MOICA setting default values of algorithm is necessary. Since values of variables are arbitrary, other values may cause better performance for algorithm. Anyway, in this paper variable are set with following variables:

$$N_{country} = 100, N_{empire} = 20, \gamma = 0.8, x = 0.2$$

Algorithm after 10 epochs has final result. In final result price of selected edges is 7650.

6 Conclusion

Actually there is a relation between number of epochs and values of default variables. In other words, some values causes to faster final result and another variables cause later final result. Unfortunately, setting the variables is arbitrary. Finding proper values may is subject for next research.

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