DYNAMIC SPECTRUM MANAGEMENT WITH MINIMIZING POWER ALLOCATION

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ABSTRACT

This paper deals with an algorithm used to manage Dynamic Spectrum (Dynamic Spectrum Management, DSM) called nonlinear programming. Now a day, DSM problem is an open problem that many scientists and researchers try to develop such an algorithm to manage the frequency ranging from 3 KHz to 300 GHz called Radio Spectrum. Radio Spectrum is quite an important range of frequencies as this range may be used for wireless communication. In this paper, the problem is proposed as minimizing power allocation since a power allocation is quite important in the competitive market. Problem is set as a nonlinear programming with example to demonstrate the algorithm as well.

Keywords: dynamic spectrum, power allocation, minimizing

1. INTRODUCTION

Dynamic spectrum management (DSM) is a very famous technology powerfully shares the spectrum among the users in the communication system. The cross-talk interference can be reduced in the digital subscriber line (DSL) while using DSM [3]-[5]. One of the promising candidates for multiple accesses in cognitive radio is also DSM [6]. There are many users coexist in a channel. This causes co-channel interference and the goal of DSM is to manage the power allocations in all channels in order to maximize the sum of the data rates of all users subject to any constraint such as power [3]. It is quite obvious that this problem is non-convex and can not be solved efficiently in polynomial time [5]. The game-theoretic formulation has been used in variety of contexts including wireless and DSL [7] since in this formulation, each user maximizes her data rate, the Shannon utility function, while given the knowledge of the other user's power allocations. Under this condition the Nash equilibrium exists and is also unique; therefore, the beauty of this formulation that the problem can be solved efficiently since it is convex. In Nash equilibrium, users tend to compete for good channels regardless the interference that might cause to the others and it is known as tragedy of the common from economics [8]. A competitive equilibrium (CE) of a market model is a set of prices and the corresponding power allocations which maximizes all user's utility and clear the market by making the total power allocated meet the spectral mask. Although the CE has become a famous problem in computer science, the application to resource communication management system is still rare. The continuation of CE for DSM was proven in [1] and also [2] show that CE achieves better total transmission rate than the Nash equilibrium. This is solved with properly assigned budgets in order to guarantee equality among all users. However, the efficient CE prices is an open problem.

[1] and [2] show that the market competitive equilibrium (CE) has become better system performance in term of data transmission rate (by reducing cross talk) compare to the Nash equilibrium (NE). [9] has shown that the CE is the solution of a linear complementarity problem (LCP) and can be computed efficiently. The reason behind this is the condition that is posted to the problem that users of a channel experience the same noise levels and the cross-talk effects between users are low-rank and weak.

This paper focuses on determining the user's budget by assuming it as power function in each channel. We show the algorithm for using as a simple model in order to demonstrate the idea on how to minimize the user's budget by using nonlinear programming.

2. PROBLEM STATEMENT

Generally, a communication system consists of n users and m channels. At the same time, multiple users may use the same channel. This will cause the interference to each other. Assuming the power that allocated by user i to channel j is $x_{ij} \geq 0$ and the total power allocated by all users in the j^{th} channel is bounded by the spectrum mask $c_j, \sum_{i=1}^{n} x_{ij} \le c_j$.

In cognitive radio, the interference experienced by the primary user due to transmissions from secondary user must be limited. For this reason, the power allocations should be scaled so that x_{ij} represents the power received by the primary user on channel j from user i . In order to achieve an efficient allocation of spectrum, we associate a price $p_j > 0$ with each channel j . Therefore, for a given vector of prices, $\vec{p} = [p_1, p_2 ..., p_m]^T$ associated with user's powers, the user's budgets will also be associated with their power as $w_j > 0$.

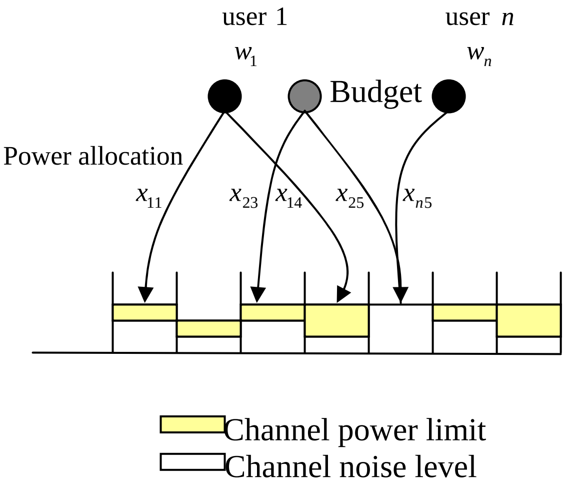

Fig. 1 Competitive spectrum market model

From above mention, the problem statement can be set as finding $x_i \ge 0$ such that

$$\min J = \sum_{i=1}^{n} w_i^2 \tag{1}$$

subject to

$$p_j + n_j \sum_{i=1}^{n_j} x_i \le w_j, \quad j = 1,..., m \tag{2}$$

$$x_i > 0, \quad i = 1,..., n \tag{3}$$

where $\vec{n} = [n_1, n_2 ..., n_m]^T$ and $\sum_{j=1}^{m} n_j = n$.

Equations (1), (2), and (3) can be solved together as set of algebraic equation and inequality equations, respectively. This is known as the form of nonlinear programming problem with sets of inequality constraints.

3. NONLINEAR PROGRAMMING

As an introduction to the problem statement, this section will focus on the use of nonlinear programming (NLP) problem. The NLP problem requires finding a finite number of unknown variables such that an objective function or performance index is optimized without violating any set of equality and inequality constraints. The NLP problem is quite often referred to as parameter optimization. It is quite known that special cases of the NLP problem include linear programming (LP), quadratic programming (QP), and least squares problems [10].

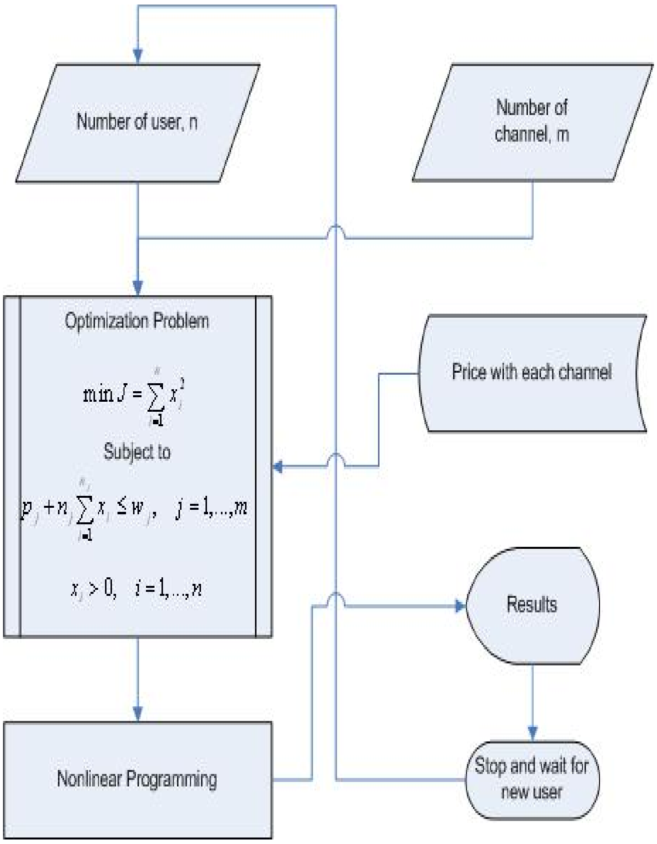

Fig. 2 A flowchart for DSM with minimizing user's budget

The general inequality constrained nonlinear programming problem can be stated as finding the n -vector $x^T = (x_1, x_2, ..., x_n)$ to minimize the scalar objective function or performance index

$$F(x) \tag{4}$$

subject to the m constraints

$$c_L \le c(x) \le c_U \tag{5}$$

and the simple bounds

$$x_L \le x \le x_U \,. \tag{6}$$

However, the the equality constraints can be included by setting $c_L = c_U$.

The necessary conditions for optimal values x^* require that

x^* must be feasible and satisfied by Eq.(5) and (6);

the Lagrange multipliers corresponding to Eq.(5) and (6) satisfy

$$g = G^T \lambda + \upsilon \,. \tag{7}$$

the Lagrange multipliers for the inequality constraints be

nonpositive for active upper bounds,
zero for strictly satisfied constraints,
nonnegative for active lower bounds.

Therefore, the optimization problem statement and nonlinear programming can be put together as a flowchart shown in Fig. 2.

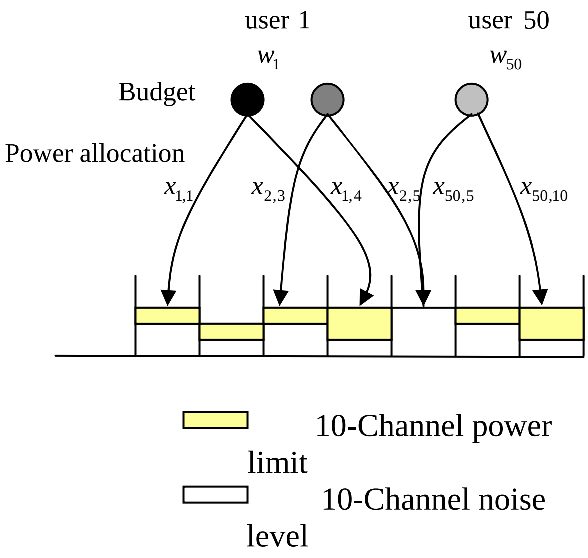

Fig. 3 Competitive spectrum market model

4. EXAMPLE

The procedure outlined in this paper for DSM with minimizing user's budget can be demonstrated by this example. Assuming that the number of users $n = 50$ and the number of channels $m = 10$. Also, in this paper, we set the price of each channel as

$$p_j = 2^{n_j}, \quad j = 1,\ldots,10 \tag{7}$$

for regulatory reason.

According to the Fig. 3 and for simple demonstration, the power that allocated by users has 5 levels as 5, 10, 15, 20 and 25. According to 5 levels of the power that allocated above, the corresponding budgets are 32, 64, 128, 256, and 512, respectively. Therefore, Eq. (1), (2), and (3) can be rewritten as

$$\min J = \sum_{i=1}^{50} w_i^2 \tag{8}$$

subject to

$$p_j + n_j \sum_{i=1}^{n_j} x_i \le w_j, \quad j = 1,\ldots,10 \tag{9}$$

$$x_i > 0, \quad i = 1,\ldots,50 \tag{10}$$

and choosing number user in each channel equally for simplicity.

Due to the inequality constraints in Eq. (9), the results from nonlinear programming show that the total user's budget from 50 users is equal to 11,360.

For the next step when some of new users is connected to these channels, all step of the computation must be recomputed again as shown in Fig. 2.

5. CONCLUSION

From the solution of the example above, the new algorithm in this paper is can be implement to the Dynamic Spectrum Management in order to minimize power allocation for the competitive market model. As known that optimization theory can be applied to many subjects and applications, there will be many goals to be achieved along this model for the future work.

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