ARTICLE IN PRESS
JID: AMC [m3Gsc;September 21, 2017;9:17]

Applied Mathematics and Computation 000 (2017) 1–12

Contents lists available at ScienceDirect

Applied Mathematics and Computation

journal homepage: www.elsevier.com/locate/amc

An efficient DCA based algorithm for power control in large scale wireless networks

Hoai An Le Thi[a,*], Anh Son Ta[b], Tao Pham Dinh[b]

[a] *Laboratory of Theoretical and Applied Computer Science EA 3097, University of Lorraine, Ile du Saulcy, 57045 Metz, France*
[b] *Laboratory of Mathematics, INSA - Rouen, University of Normandie, 76801 Saint-Etienne-du-Rouvray Cedex, France*

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Power control
Wireless communications
Quality of service (QoS)
DC programming
DCA

ABSTRACT

In recent years, power control and resource allocation techniques for cellular communication systems are very active research areas. Power control is typically used in wireless cellular networks in order to optimize the transmission subject to quality of service (QoS) constraints. One of the most popular power control problems is based on maximizing the weighted sum of data rates under the peak power constraints for all users. It is a difficult nonconvex optimization problem for which standard approach Geometric Programming is not applicable in large scale setting. In this paper, we propose an efficient method based on DC (Difference of Convex functions) programming and DCA (DC Algorithm), an innovative approach in nonconvex programming framework for solving this problem. The purpose is to develop fast and scalable algorithms able to handle large scale systems. The two main challenges in DC programming and DCA that are the effect of DC decomposition and the efficiency of solution methods to convex subproblems are carefully studied. The computational results on several datasets show the robustness as well as the efficiency of the proposed method in terms of both quality and rapidity, and their superiority compared with the standard approach Geometric Programming.

© 2017 Published by Elsevier Inc.

1. Introduction

The technology and business of wireless communication system have been developed dramatically since 1990s. Today, the mobile telephone success story calls the wireless communications community to turn its attention to other information services, most of them in the category of “wireless data” communications. Wireless technology is a truly revolutionary paradigm shift, enabling multimedia communications between people and devices from any location. It also underpins exciting applications such as sensor networks, smart homes, telemedicine, and automated highways. Nowadays the wireless networks are becoming an innovative business environment in which new values can be created by competing as well as collaborating enterprises through innovation. Wireless networks significantly contribute to the seamless collaboration and interoperability within and outside the enterprises.

The radio resources management (power control, channel assignment, and handoffs) is crucial in wireless networks, and therefore, it is vital to develop advanced radio resource management techniques on wireless systems. One major issue of the radio resource management is power control. Power control and resource allocation techniques for cellular communication

* Corresponding author.
E-mail addresses: hoai-an.le-thi@univ-lorraine.fr (H.A. Le Thi), taanhson123@gmail.com (A.S. Ta), pham@insa-rouen.fr (T. Pham Dinh).

http://dx.doi.org/10.1016/j.amc.2017.08.061
0096-3003/© 2017 Published by Elsevier Inc.

Please cite this article as: H.A. Le Thi et al., An efficient DCA based algorithm for power control in large scale wireless networks, Applied Mathematics and Computation (2017), http://dx.doi.org/10.1016/j.amc.2017.08.061

systems have been intensively studied [1–3]. It has been proposed to use the user signal to interference plus noise ratio (SINR) to adjust the transmitted power [4]. This is particularly important in CDMA (Code division multiple access) systems, where users transmit at the same time over the same frequency bands and their spreading codes are not perfectly orthogonal. Transmit power control is often used to tackle this problem of signal interference [5]. In this way, power control is used to control interference, and therefore, to control also individual user's quality of services (QoS). Various objectives have been considered for developing power control algorithms. For example, one can maximize the minimum SINR, minimize total transmitted power, or minimize outage probability in a cellular network [1,4,6,7]. The objective represents a systemwide goal to be optimized; however, individual users' QoS requirements also need to be satisfied. Any power allocation must be satisfied by these minimum requirements constraints from the users. Because a higher power level from one transmitter increases the interference levels at other receivers, there may not be any feasible power allocation to satisfy the requirements from all the users. Sometimes there exists a solution which can be satisfied the set of requirements, but when a new user is admitted into the system, the power control requirements are modified, and then this solution is no more feasible, or even if it is feasible, it may not be optimal. These two situations lead to the need for admission control and admission pricing, respectively (see [8]). Although various iterative methods have been developed to solve the power control problem in cellular wireless systems, these methods are not general to allow a diverse set of QoS constraints and objective functions.

A general framework for the power control based on *geometric programming* (GP) was developed in [1,9]. However, in order to enable the application of geometric programming to solve the throughout maximization or weighted sum of data rates maximization problems, $\mathrm{SINR}+1$ has to be approximated as SINR. Unfortunately, such approximation might be very imprecise and loose, especially at low SINR regime which is a usual scenario for systems with CDMA applications. Moreover, note that the aggregate system throughput or sum of $\log(1+\mathrm{SINR})$, is the actual target for network optimization. It turns out that the resulting problem is NP-hard. Although the original formulations can be solved using the method of successive convex-approximation as described in [1], the number of iterations, i.e., the number of geometric programs that need to be solved, may be large, and thus, leads to high overall complexity. Moreover, global optimality is also not guaranteed.

QoS provisioning in a wireless network is a particularly difficult task because physical layer problems; such as path loss, fading, and multi-path; can make the communication links unreliable. Since the channel gains vary all the time, there is a need for low-complexity algorithms to carry out resource allocation, i.e., power control, in wireless networks. Moreover, such algorithms should also provide good performance in order not to waste radio resources. This is precisely our aim in this work. Specifically, in this paper, we directly consider the aggregate system throughput as objective function in solving the power control problem for cellular systems. We show that the corresponding optimization problem belongs to the class of so-called DC (Difference of Convex functions) programming problems and propose a *low complexity* DCA (DC Algorithm) based algorithm [10–14] to solve the resulting DC problem. Albeit sub-optimal, the proposed approach achieves *near optimal* results. Our aim is to develop fast and scalable algorithms which can handle large scale systems.

DC programming and DCA (DC Algorithms) (see [10–14] and the references in [15]) are powerful tools in nonconvex programming framework. DCA aims to solve a standard DC program that consists of minimizing a DC function $f=g-h$ (with g and h being convex functions) over a convex set or on the whole space. Here $g-h$ is called a DC decomposition of f, while the convex functions g and h are DC components of f. The main idea of DCA is approximating the second DC component h by its affine minorant and then solving the resulting convex subproblem at each iteration. The construction of DCA involves DC components g and h but not the DC function f itself. Hence, for a DC program, each DC decomposition corresponds to a different version of DCA. Since a DC function f has an infinite number of DC decompositions which have crucial impacts on the qualities (speed of convergence, robustness, efficiency, globality of computed solutions, ...) of DCA, the search for a "good" DC decomposition is vital from algorithmic point of views and is the most important key issue while designing DCA for a practical problem. Furthermore, how to efficiently solve convex subproblems in DCA is a crucial question as well (evidently the form of convex subproblems depends on the DC decomposition). In fact, although convex programming has been studied for about a century, an increasing amount of effort has been put recently into developing fast and scalable algorithms to deal with large scale problems. Moreover, as DCA is a local approach, finding a good starting point is also an important matter to be studied.

In this paper we investigate DCA for the power control problem in large scale systems by considering all the above key issues in a deep way. Our contributions are threefold.

Firstly, we exploit the special structure of the objective function in a suitable way to propose a *good* DC decomposition. The resulting DCA involves the convex subproblem which is a strongly convex quadratic program, thus it can be efficiently solved by standard softwares. Moreover, this convex subproblem is nothing else a projection problem which consists of computing the projection of a point onto a polytope having a very specific structure.

Secondly, we develop a low complexity projection algorithm to the projection problem in the DCA scheme by exploiting the special structure of the feasible set in a deep and efficient way. It turns out that our projection algorithm is either defined by a very simple formula (the projection of points onto a box) or determined in a very inexpensive way with the complexity $O(K)$ with K being the number of users in the system (the projection of points onto the intersection of a box and a hyperplane). This significantly increases the speed of the proposed DCA. The numerical experiments show that our DCA is far faster than the standard GP approach, the ratio of gain can up to $12,734$ times for a small network having 28 users. Further, DCA can solve large scale problems in a very short time: we need less than 1 second for handling a network having 500 users.

Download English Version:

https://daneshyari.com/en/article/8901591

Download Persian Version:

https://daneshyari.com/article/8901591

Daneshyari.com