A Unified Graph Labeling Algorithm for Consecutive-Block Channel Allocation in SC-FDMA

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***Abstract*—In SC-FDMA (single-carrier frequency-division multiple access) with localized channel assignment, the channels of each user must form a consecutive block. Subject to this constraint, various performance objectives have been studied. We present a unified graph labeling algorithm for these problems, based on the structural insight that SC-FDMA channel allocation can be modeled as finding an optimal path in an acyclic graph. By this insight, our algorithm applies the concept of labeling and label domination that represent non-trivial extensions of finding a shortest or longest path. The key parameter in trading performance versus computation is the number of labels kept per node. Increasing the number ultimately enables global optimality. The algorithm's approach is further justified by its global optimality guarantee with strong polynomial-time complexity for two specific scenarios, where the input is user-invariant and channel-invariant, respectively. For the general case, we provide numerical results demonstrating the algorithm's ability of attaining near-optimal solutions.**

I. Introduction

In SC-FDMA systems, there are two schemes of assigning channels to users: localized and interleaved. In the former, each user is assigned a block of channels that are consecutive in the spectrum. In the latter, the channels of a user is spread out, with equal spacing between them. In this paper, we focus on the optimal channel allocation problems with localized channel allocation. We present a unified study of consecutive-channel resource allocation for three optimization problems, i.e. maximum utility, minimum power, and minimum number of used channels. We prove that the three resource allocation problems are NP-hard.

II. Unified Graph Labeling Algorithm

We provide the structural insight that allocating blocks of consecutive channels optimally can be mapped to finding an optimal path in an acyclic graph. With this insight, we develop a unified graph labeling algorithm (GLA). We define a directed and acyclic graph $G = (V, A)$ as shown in Fig. 1. In graph G, an arc corresponds to grouping channels into

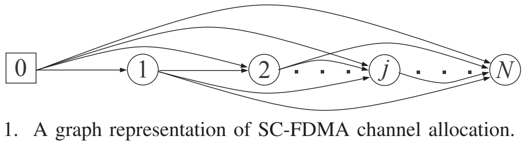

Figure 1. A graph representation of SC-FDMA channel allocation.

a channel block. An arc is associated with values to specify the performance metric of assigning the block to users, i.e., utility, power, and number of channels. Traversing arc (j, k) corresponds to considering allocating the $k - j$ consecutive channels to candidate users that were not yet allocated any channel resource, as well as the option of not assigning the block to any user.

From Fig. 1, a solution to the three channel allocation problems has a unique mapping to a path from node zero to node N in graph G. This is in fact a type of optimal path problem, i.e., to find either a longest (utility maximization) or shortest (power minimization and channel minimization) path in the acyclic graph G. Based on this graph representation, the GLA algorithm carries the following features: 1) Multiple labels are used for each graph node, which allows multiple partial solutions to be tentatively stored, enabling better solution quality than allocating channels in a pure greedy manner. 2) The labels are organized into buckets, where each bucket corresponds to partial solutions with the same number of users that have been allocated channel blocks so far. This bucket classification limits competition among partial solutions to those in the same bucket, and hence avoids an overly-greedy approach. 3) We introduce the concept of label domination to identify partial solutions that can be dropped without any loss of optimality. 4) By treating bucket size as an algorithm parameter, the GLA allows a flexible trade-off of complexity and system performance. Analytically, the algorithm ultimately approaches global optimum when the bucket size is sufficiently large. 5) The GLA has the global optimality guarantee for two specific scenarios, i.e. user-invariant and channel-invariant.

III. Performance Evaluation

Performance evaluation shows that GLA is highly competitive in attaining close-to-optimal solutions. The performance is superior in comparison to known algorithms in the literature for all three objectives. Moreover, GLA exhibits very promising performance in reaching feasible allocations for the two minimization problems, where finding a feasible solution is challenging for high user demand.

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