Resource Allocation in OFDMA as an Optimization Problem

Álvaro Pachón
Universidad Icesi, Colombia

Ubaldo García-Palomares
Universidad de Vigo, Spain

Juan Manuel Madrid
Universidad Icesi, Colombia

INTRODUCTION

Wireless mobile communication systems (WMCS) face the challenge of satisfying the requirements of an increasing number of users demanding diverse services. WMCS service providers have multiple challenges: increasing number of users, full satisfaction of service requirements, and introduction of new technologies. Adequate resource management becomes a key factor for guaranteeing a successful relationship between service provider and users, for meeting system performance goals, and to achieve financial sustainability.

This article presents the formulation and solution of the *resource allocation problem* in a WMCS. Treated topics include the problem definition, the reasons for being a research problem for the academic community, the identification of the solution's technological context, and different approaches for its solution.

BACKGROUND

Problem Definition

The resource allocation problem can be stated as assigning resources (frequency and power blocks) with efficacy and efficiency, to a number of users demanding a variable set of services within a geographical area, accomplishing a balance between full satisfaction of user service requirements, and service provider financial/operational sustainability.

Problem Importance

The problem has two perspectives: a) The engineering perspective, since it is necessary to understand the challenges network operators face to offer services; and b) the service perspective, because success of the service provider depends on the variety of services offered to users, and the capacity to fully satisfy them.

Application Context

The context for problem formulation and solution is the downlink of a LTE (Long-Term Evolution) WMCS. LTE uses *OFDMA* (Orthogonal Frequency Division Multiple Access) as its multiple access technique at physical level.

OFDMA is a multiple access technique adopted by next-generation WMCS for their radio access interface, combining frequency and time domain access. Hence, the radio resource is represented in a time-frequency space, known as a resource grid. Channel bandwidth is divided into an orthogonal set of narrow-band carriers, allowing conversion of high serial data rates of broadband channels into parallel, orthogonal sets of smaller speed narrow-band channels, which experience flat frequency fading.

LTE, introduced by 3GPP, constitutes the evolution of cellular mobile communications towards a wideband end-to-end IP network. Several of its features are related to this article's proposal: a) Use of OFDMA as the downlink multiple access technique; b) use of adap-

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tive modulation and coding (AMC) schemes, selected according to channel condition and services demanded by users; and c) a high spectral efficiency requirement, leading to adoption of 1/1 frequency reuse schemes. In LTE, subcarriers in a channel are grouped in subsets known as Resource Blocks (RB). The average value of the SINR (Signal to Interference plus Noise Ratio) fully describes the subcarrier set, and determines the quality of received signal, the modulation/coding scheme to be used, and the achievable data rate.

APPROACHES TO SOLUTION OF THE PROBLEM

The resource allocation problem in OFDMA offers multiple degrees of freedom, including implementation of the resource allocation task, time perspective for task execution, services offered by the service provider, WMCS architecture, optimization criterion, and resource scheduler architecture.

Implementation of the Resource Allocation Task

González et al. (2009) and Cicalo et al. (2011) propose two approaches for resource allocation:

- Distributed approach. It enables each node to autonomously allocate resources, making the task simpler, lighter and less prone to failure in the computational sense. However, a global view of the system is not possible with this approach.
- Centralized approach, featuring a central coordinator node. This node receives information from all other nodes, and performs resource allocation. Thus, it is possible to determine the global system status, in order to mitigate generated interference. Disadvantages of this approach include coordinator overload and/or failure (single choke point).

Time Perspective for Task Execution

González et al. (2009) consider two different time scales for task execution: Frame-level scale (millisecond level), which allows allocating frequency blocks to users; and superframe-level scale (2 or 3 orders of magnitude greater), which allows mitigating interference generated in the system.

Services Offered by the Service Provider

The WMCS can serve two different scenarios: homogeneous, which offers same services to all users; and heterogeneous, which can offer different services to each user. Coexistence and scheduling of such services constitutes an enormous challenge to the service operator.

WMCS Architecture

The WMCS can be deployed following two architectures: homogeneous architecture, in which all cells have the same coverage, power and intended usage; and heterogeneous architecture, which features low power nodes that improve system capacity, but complicate deployment and interference management.

Optimization Criterion

Kuo et al. (2007) state the great importance of balancing WMCS performance and full user satisfaction. Thus, the problem solution can be either performance-oriented (aimed to adequate resource usage) or service-oriented (aimed to user satisfaction).

Resource Scheduler Architecture

Iosif and Banica (2011) divide resource allocation into two activities: User scheduling, which identifies users that must receive service in the time *t*, and resource allocation, which allows quantifying the needed physical resources to satisfy the user's demands. The resource scheduler executes these activities in the base station.