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Joint Uplink/Downlink Resource Allocation in OFDMA Wireless Networks

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Abstract: *Recent technologies mainly focuses on schemes in which uplink and downlink resources are considered independently. We propose a new approach where uplink and downlink resources are jointly allocated to all users in an OFDMA based cell using game theory. In our context, the players are 'wireless nodes' which are either cooperative or non cooperative. In our paper, we consider an application of game theory to address problem of resource allocation, specifically power allocation. Joint uplink/downlink subcarrier allocation will yield higher performance gain. This schemes can be used for applications like gaming, multimedia streaming and mobile social networks where uplink data rate should be high. This will notably improve user's end-to-end interaction.*
Index Terms: *Joint allocation, Downlink ,Game theory, OFDMA based cell, Uplink.*

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I. Introduction

There is huge demand in high uplink data rate resource-demanding wireless applications such as gaming, multimedia streaming, and mobile social networks which requires an efficient management and allocation of the scarce radio resources. To meet this growing demand requires wireless services which adhere to strict quality-of-service (QoS) requirements. This requires novel approaches for resource allocation in OFDMA based wireless systems such as LTE and WiMAX. Recent technologies mainly focuses on schemes in which uplink and downlink resources are considered independently. However, many emerging wireless services are expected to involve end-to-end interactions between the users. For such services, there is a need for new approaches to optimize performance taking into account, jointly, the uplink and downlink QoS requirements of the users.Whenever one deals with a joint UL/DL resource allocation problem, it is of interest to devise distributed solutions in which the users can take individual decisions on which carriers to obtain, jointly on the UL and DL, depending on the choices of the other users. In this respect, it is of interest to adopt game theoretical techniques for modeling and finding efficient solutions for joint UL/DL resource allocation. In this paper we propose using game theory approach to allocate subcarriers to users. Game theory is the approach which is study of formal interaction of several decision makers where each player is playing independently. Similarly, interaction between wireless terminals like mobile phones is naturally present in wireless networks, since interference often exists or/and common resources must be shared. In present scenario wireless networks have evolved enormously and new communication paradigms have appeared, making game theory specially relevant in their analysis and design. The purpose of using game theory is to model interactions between players and to predict all possible outcomes and to characterize it so it would yield best strategy. Players are mobile nodes. Also we have considered a non-cooperative model. Type set of any player i is the set Ti of time intervals ti during which the player wants to connect to the wireless access point. Payoff is defined as the difference between the utility of allocated data rate and the cost paid to wireless access point. Using simulations, we demonstrate that the proposed algorithm yields notable performance gains relative to classical resource allocation schemes.

II. System Model

We consider a single cell in an OFDMA network with M active users having connections that require joint uplink/downlink QoS guarantees (e.g., symmetrical services). These connections can be with other users in the same network or in other networks. Furthermore, we consider KU and KD subcarriers that need to be distributed among the users in the uplink and downlink, respectively. The available power is assumed to be distributed equally over all allocated subcarriers as equal power allocation has shown very good performance compared to optimal frequency-selective power allocation.

The instantaneous rate of user i in the uplink and downlink are given by:

- Uplink data rate $R_i^U = \sum_{j=1}^{K} wij\ log_2(1 + Pj * \gamma ij/wij)$
- Downlinkdatarate $R_i^D = \sum_{j=1}^{K} wij\ log_2(1 + Pj * \gamma ij/wij)$

Where R_i^U = uplink data rate, R_i^D = downlink data rate, Wij = weighted function to user i on subcarrier j in uplink and downlink, Pj = power allocated to each user, γij = channel to noise ratio to user i on subcarrier j in uplink and downlink.

In general, for resource allocation schemes in which the objective is to maximize the sum-rate achieved by the users in the network, full Channel State Information (CSI) is required in order to reap the benefits of multiuser diversity. The base station has only a knowledge of the uplink CSI and the users of the downlink CSI.

In order to capture the performance coupling between the uplink and downlink directions of any user i, we will use a constraint on the difference between the achieved uplink rate (RU) and downlink rate (RD). This difference is assumed to be bounded by a constant δi as follows:

- Joint uplink/downlink utility function $U(i) = -|R_i^D - R_i^U| \leq \delta_i$

In essence, the main objective of the proposed resource allocation approach is to balance the rates of each user in the network between the uplink and the downlink using the coupling. The constant δi is a parameter that could be set by the network operator on a service level basis and reflects the required relation between uplink and downlink rates. The coupling between the uplink and downlink mandates a proper assignment of the subcarriers in both directions to the different users.

III. Algorithm

- Total no of users in one OFDMA cell
- Total bandwidth is fixed which is shared among users
- Allocate subcarriers to each user
- Calculate power for each user in uplink
- Put the constraint and maximize it using for loop
- Calculate power of each user in downlink by adding uplink data rate with constraint

There are two steps to this process. In first step, we will use GAME THEORY approach to allocate subcarriers to users. We will run a non cooperative stable two-sided stable matching game in absence of channel state information. In this the main consideration would be user's payoff. Depending on how much a user is willing to pay, that many subcarriers will be allocated to him. In this process we will match the no of subcarrier to the user. In the second step we will run a distributed resource allocation algorithm suitable for both symmetrical and asymmetrical services with joint uplink/downlink QoS requirements. This algorithm will maximize a utility function that captures joint uplink/downlink QoS requirements. The resulting matching will be fair and stable in a sense that no user can improve its utility by switching its current subcarrier. The proposed approach uses a distributed approach instead of conventional centralised approach. For simplification, we have assumed that all users in the OFDMA cell and no handoffs are required.

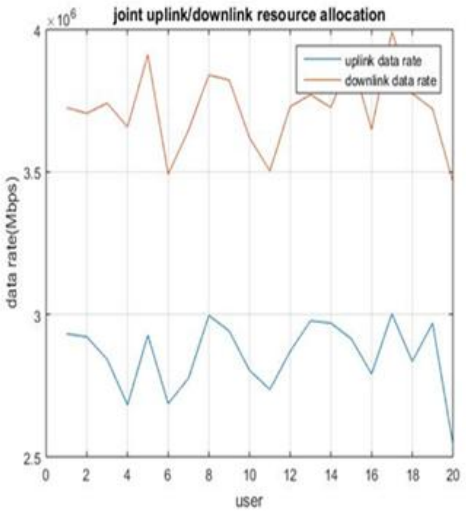
IV. Numerical Study

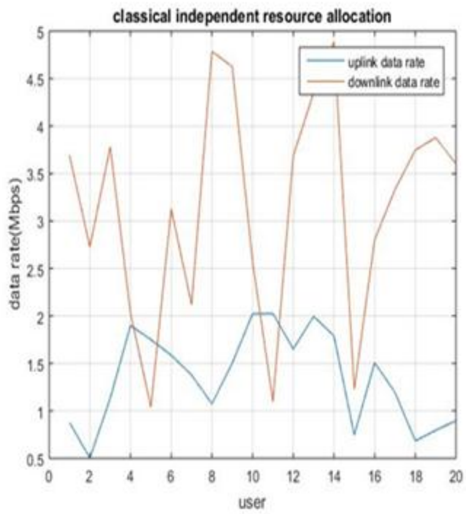
For our simulations, we consider a single-cell in an OFDMA network with M users and a BS located at the cell center. We consider a Rayleigh fading channel and, hence, the channel gain of each user is exponentially distributed with mean equal to the path gain representing propagation loss and given by Kd_i^{-x}, with κ a constant chosen to be −128.1 dB, di the distance in km from user i to the BS, and x the path loss exponent set to a value of 3.76. We study a scenario of M = 20 users located at an equal distance, fixed to 200 m from the BS. We consider a bandwidth of 5 MHz in the uplink and the downlink divided into KU = 64 and KD = 64subcarriers, respectively. The power budget of the users is Pmax = 125 mW and the power budget of the BS is PBS = 30W. The power allocation is done via equal power allocation where the uplink power budget of a user is divided equally among subcarriers allocated to it whereas in the downlink the power budget of the base station is divided equally among all subcarriers. The value of δ is set to 1 Mbps.

SYSTEM MODEL

PARAMETERS	VALUES
No of users in an OFDMA cell	20
Total bandwidth shared among users	5 MHz
Total no of subcarriers	64 subcarriers
Max power by user	125 mW
Max power by base station	30 W
Distance range of user from BS	200 m to 650 m
Path loss exponent	3.76

V. Results





Here joint uplink and downlink resource allocation is proposed algorithm and improvement of classical algorithm

The resulting uplink and downlink rates achieved by using the proposed stable matching resource allocation algorithm are shown in Figure 1. Although, the users are placed at an equal distance from the base station, the channel variations lead to different achieved rates by the users. The result also demonstrate the desired coupling between the uplink and downlink. From Figure 1, we can clearly note that the downlink rate achieved is always within δ of the uplink rate. Moreover, the joint resource allocation via stable matching lowers the effect of the difference in the available power between the base station and the mobile users which usually translates into large rate differences between the two communication links. In Figure 2, we show the uplink and downlink rates for a classical independent resource allocation scheme which serves as a benchmark with which we compare our proposed algorithm. By this approach, the radio made more intelligent so that it can allocate resources more efficiently without any unfair policy in a competitive environment without any unfair policy in a competitive environment.

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