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Resource allocation and relay selection in full-duplex cooperative orthogonal frequency division multiple access networks☆

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ABSTRACT

This paper is on relay selection in uplink of an in-band full-duplex (IBFD) cooperative cellular network. Assuming an orthogonal frequency division multiple access (OFDMA) cellular network, we develop a relay selection and resource allocation algorithm for this network. The relay selection algorithms select the best relay based on distance between users and signal to interference plus noise ratio (SINR) that operate in amplify and forward (AF) mode. The optimization problem allocates the optimum subcarriers and powers to all users to maximize the average sum-rate of the network. In addition, the constraints of the optimization problem are quality of service (QoS) and transmit power of each user. Simulation results illustrate the good performance of the proposed method.

1. Introduction

The inevitable high bandwidth requirement in the future cellular networks has led to advent of new technologies. One of this technologies is in-band full-duplex (IBFD) communication. IBFD systems can transmit and receive signals at the same time on the similar frequency band with self-interference (SI) that can be reduced by propagation-domain, analog-circuit-domain, and digital-domain cancellation approaches [1]. If a wireless terminal in a cellular network operates in full-duplex mode, it can potentially double the spectral efficiency of the network relative to half-duplex mode.

In recent years, cooperative communications has been known as one of the main techniques to improve the capacity and coverage that one or more nodes help other nodes to make a better communication [2–5]. Cooperative communication is a key enabling technology for optimum spectrum use that applies resource sharing between multiple nodes in the network. This technology has many advantages such as improved coverage, throughput, system capacity, power/battery life and etc. Amplify-and-forward (AF) and decode-and-forward (DF) are the most common relaying strategies in cooperative communications [5–8]. In the DF method, the relay re-modulates and retransmits the received noisy signal [5,6], while in the AF method relay only amplifies and retransmits its received signal [4–6]. The complexity of a DF relay is similar to a base

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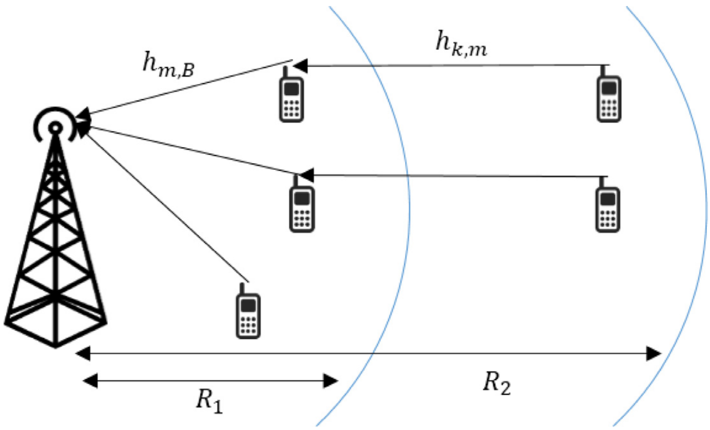

Fig. 1. System model.

station and is higher than an AF relay [9]. It is also possible to apply orthogonal frequency-division multiplexing (OFDM) in cooperative communication to provide improvement in data rate specifically for broadband wireless networks [4,7,8].

A review on previous works in full-duplex networks illustrates that the most of studies have been performed for non-cooperative networks (i.e. when only a direct link between the BS and users exists) [10]. For cooperative communications in full-duplex networks, two modes exist: installing fixed relays and exploiting users as relays [11–14]. On the other hand, all of these papers only consider the downlink transmission. [11,12] and [15] are based on orthogonal frequency division multiple access (OFDMA) that using subcarrier pairing in the relay network can result in the frequency diversity, and hence, improves system performance [16]. Some papers propose a scenario that there are one source and destination and some relays between them [13].

One of the other techniques in a cooperative network that can improve the network performance is relay selection. This technique can also be used in full-duplex cellular cooperative networks. There are several relay selection schemes proposed for amplify and forward (AF) and decode and forward (DF) networks [17,18]. The proposed relay selection methods in [17] are based on channel coefficients, and methods in [18] are based on distances between nodes.

In this paper, we investigate the effect of relay selection schemes on the total sum-rate of the full-duplex cellular cooperative OFDMA networks. The cooperative network is based on AF relay nodes that are selected from the users that are close to the BS. Afterward, we optimize the allocation of powers to all users and then select the best relay for each of far users. After relay selection, the OFDMA subcarriers are optimally allocated to all users.

Finally, we have a total sum-rate maximization problem based on relay selection in which the power and quality of service for each user are our constraints. We prove that the problem can be converted to a convex optimization problem and then, we can solve it with numerical methods. Our simulation results demonstrate the performance of our system model and its effect on the total sum rate of the network.

The contributions of this paper are as follows. We investigate uplink of an IBFD-OFDMA cooperative cellular network. In this network, users that are not in the BS's coverage area can communicate with the BS by help of the relays. In our system model, all nodes are IBFD and we analyze the SI effect in the BS on the sum-rate. We consider the large-scale path loss based on users' location. In the subcarrier assignment, we applied the Munkres algorithm [19] to trust that in each time slot, each subcarrier assigned to only one user. We propose relay selection algorithm based on channel coefficient and location of users to choose the best relay to connect users and the BS. Our optimization problem is a sum-rate maximization problem of subcarrier and power allocation with power and quality of service constraints for each user. This problem is a mixed integer nonlinear program (MINLP) that is non-convex. We relax and convert it to a convex problem and then, solve it with numerical methods.

The remainder of this paper is organized as follows. The system model is introduced in Section 2. Relay selection schemes are introduced in Section 3. Problem formulation for sum-rate maximization is introduced in Section 4. The simulation results are demonstrated in Section 5. Finally, Section 6 concludes the paper.

2. System model

We consider uplink of a single cell network which consists of a BS at the center of the cell and two groups of users around it, as depicted in Fig 1. All users and the BS operate in full-duplex mode. Our OFDMA cellular network's total bandwidth is NW, where N is the number of subcarriers and W is the bandwidth of each subcarrier that is the same for all subcarriers. The users of the first group that have far distance to the BS, to communicate with the BS transmit their data to users of the second group that have short distance to the BS. The users of the second group for relaying the received signal from far users that are not in the BS coverage area to the BS, use amplify and forward relaying strategy. The number of users is $K1 + K2$ that $K1$ is the number of users in the first group and $K2$ is the number of users in the second group.