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AMC-based resource allocation in adaptive frequency reused OFDMA-relay networks

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Abstract

In orthogonal frequency division multiple access (OFDMA) relay system, for supporting relay transmission, the base station (BS)-the relay station (RS) link must consume an extra part of resource, which may result in serious resource shortage. In order to improve resource utilization, this paper proposes a dynamic resource allocation scheme in adaptive frequency reused OFDMA-relay system based on adaptive modulation and coding (AMC) technology. In this scheme, relay nodes have two independent antennas and operate in decode-and-forward (DF) and full-duplex mode. Then the BS and RSs share the same subcarriers by spatial multiplexing by two independent antennas. The resource allocation problem is formulated for system downlink throughput maximization. Since the optimal solution couldn't be obtained easily, a sub-optimal algorithm is proposed. The adaptive frequency reused algorithm with two independent antennas RS improves the system throughput about 24.3% compared with the orthogonal frequency allocation with single-antenna model, and increases the system throughput 10.4% compared with adaptive frequency reused algorithms with single-antenna RS. It is proved that both of the RS with two-antenna model and adaptive frequency reused scheme can improve the system throughput significantly.

Keywords AMC, resource allocation, adaptive frequency reuse, OFDMA, relay

1 Introduction

In OFDMA system, the user diversity could be implemented by carefully select the proper frequencies. Recently some papers have proposed the dynamic subcarrier allocation, bit allocation and power distribution solutions to increase the cell throughput and improve the spectral efficiency [1–3]. In next generation communication, the relay technology is introduced in 802.16j, 802.16m and LTE-advanced to provide broader signal coverage, higher data transmission rate, and faster mobility. However, in relay system, the BS-RS link must consume an extra part of resources, and it may result in more resource shortage. Many previous researches focused on the orthogonal resources (in time or frequency) allocated to the users in the cell of the relay system [4]. They divide the bandwidth into many fixed frequency bands, and then different RS and BS are allocated different orthogonal resources by a resource management policy. Ref. [5] proposed the optimal algorithm in half-duplex relay system with the sub-channel allocated to achieve maximum system throughput. To save the resources used in BS-RS link, the work on relay-based network assume that RS can transmit and receive simultaneously in the same subcarriers, i.e. work on full-duplex mode [6]. However there are many limitations in radio implementation preclude the terminals from this operation. Therefore there lack of sufficient studies about adaptive-reuse subcarrier allocation between BS and RS based AMC relay system.

In this paper, suppose BS and RSs share the same frequency through AMC and spatial multiplexing by using the DF relay with two independent antennas. The target is to maximize the system throughput of a broadband cellular OFDMA system with the adaptive frequency reuse between BS and RSs. Because the optimal algorithm is a non-linear optimization problem with integer variables, this paper proposes a sub-optimal algorithm. The sub-optimal algorithm uses the characteristic of the AMC-based system, which can

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tolerate some interference. Then the subcarriers are adaptively chosen to the BS or an RS or both, through channel state information (CSI) and the condition of the interference. And the subcarriers assignments for BS and RS are separated, that simplify the non-linear optimization with integer variables.

2 System model

This paper considers an AMC-based multiuser dual-hop downlink system with minimum data rate constraints for each MS. The system has *K* active mobile stations (MSs), *M* RSs and a single BS, as shown in Fig. 1. It is denoted that the first hop is the BS-MS link or BS-RS link, and the second hop is the RS-MS link. It is assumed that the wireless channel between each pair of transmitting and receiving nodes is frequency selective, and OFDMA is employed for data communication to divide the channel into a set of *N* orthogonal subcarriers with flat channel responses and additive white Gaussian noises (AWGN). Furthermore, all MSs and the BS in the system are equipped with a single antenna. All RSs use the model with two antennas, an omni-directional antenna for the RS-MS links and a directional antenna for the BS-RS link, i.e., for receiving DL data from the BS. This detailed model is described in Ref. [7].

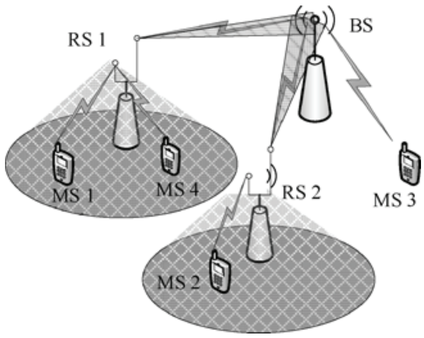

Fig. 1 System model

AMC can be independently applied to each link in the system because of using DF RS. The selected modulation and coding scheme (MCS) might be different for both hops. Therefore the subcarrier can select MCS according to SINR denoted as γ, and the rate of the MCS can be simply expressed as

$$f(\gamma) = \max\{c \mid c \leqslant \text{lb}(1+\gamma), c \in \{c_0, c_1, ..., c_w\}\} \quad (1)$$

where $c_0, c_1, ..., c_n$ are the corresponding rates of MCSs, which are all constant. As an example, $w = 7$ and different MCSs are listed in Table 1 [8], the bit error rate (BER) is 10^{-6}.

Table 1 SINR of different coding–modulation schemes

Coding rate and modulation level combination	Spectral efficiency/ $(\text{bit} \cdot \text{s}^{-1} \cdot \text{Hz}^{-1})$	SINR at 10^{-6} BER/dB
QPSK 1/2	1.00	4.65
QPSK 3/4	1.50	7.45
16-QAM 1/2	2.00	10.93
16-QAM 3/4	3.00	14.02
64-QAM 2/3	4.00	18.50
64-QAM 3/4	4.50	19.88
64-QAM 7/8	5.25	21.94

We also assume that the two antennas are independent of each other, and the directional antenna's beam is very narrow. Therefore the RS-MS link doesn't interfere with the BS-RS link when the two links use the same resources simultaneously. The subcarriers in BS-RS link can be reused in the RS-MS link. The rate under AMC is discrete, and the link with AMC can tolerate some interference. For this reason some subcarriers used in BS-MS link can be also used in RS-MS link if the interference is acceptable. Thus the BS and RS can use the same subcarrier, i.e. the BS and the RS reuse the adaptive frequency band. However sharing a subcarrier by BS or different RS is not allowed where the BS serves as the central planner for the cell that controls the resource allocation of all users and all relays with all CSI (channel state information). Additionally, the average transmit power of each subcarrier of both BS and RS, on the other hand, is kept constant. The average power of subcarrier transmitted from BS is P_{BS}, and the one transmitted from RS is P_{RS}. Next section will focus on the downlink resource allocation for the system, which maximizes the system throughput.

3 Problem formulation

In this paper, *R* denotes the minimum required rate of users. For each subcarrier of index *n*, $\rho_{k,n}$ is defined to indicate whether the *n*th subcarrier is allocated to the BS-the *k*th MS link or BS-RS link, and $q_{k,n,m}$ indicates whether the *n*th subcarrier is allocated to the *m*th RS—the *k*th MS link. $A_{k,n}$ denotes the SINR of the link between BS and the *k*th MS. $B_{k,n,m}$ denotes the SINR of the link between the *m*th RS and the *k*th MS. $C_{n,m}$ denotes the SINR of the link between BS and the *m*th RS. Since the transmission in relay system includes both direct transmission and relayed transmission, it needs to define subcarrier assignment indexes to calculate achievable rate of user *k* for distinguishing direct transmission from relayed transmission. Assignment indexes α_k and β_k are defined as