Downlink Scheduling for Multi-Cell MIMO Systems

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Abstract: In this paper, we study about downlink scheduling for multi-cell multiple-input multiple-output (MIMO) systems. The inter-cell interference experienced by a user is quietly a pre-eminent issue in the communication scenario.Specifically, the performance degradation for the cell-edge users who experience significant inter-cell interference is severe, which may limit the overall system performance. As a result, continuous streaming is not possible and leads to ineffective communication. So in order to overcome these difficulties, we formulate an optimization problem which aims at jointly selecting a user and connecting the user to the tower with high signal strength. We first obtain a calibrated value of signal strength and the distance between tower and the user, which is collectively termed as the RSSI value. The pre-determined RSSI value is fed to the scheduler along with the signal strength to decide as to which tower the user should be switched to. Simulation results show that the performance of the proposed system is better than the existing systems.

Keywords: Scheduling, RSSI, CSI, LDPC.

I. INTRODUCTION

Next generation wireless communication systems, such as the 3rd Generation Partnership Project (3GPP) Long Term Evolution Advanced (LTE-Advanced) system, aim to provide high speed data services with limited radio resources. Multi-cell processing combined with multiple-input multiple-output (MIMO) transmission has been proposed as a promising solution to improve spectral efficiency and system throughput. The conventional spatial multiplexing MIMO transmission strategy can achieve high data rates by transmitting multiple data streams simultaneously. However, in multi-cell systems where the same carrier frequency is reused by several adjacent cells, the performance of spatial multiplexing is limited due to inter-cell interference. Specifically the performance degradation for the cell-edge users who experience significant inter-cell interference that may limits the overall system performance.

Recently, interference alignment has emerged as an effective technique to suppress inter-cell interference in multi-cell MIMO systems. The main idea is that base stations jointly design precoding and decoding matrices based on the channel state information (CSI) of all individual links such that the signals transmitted from interfering base stations are aligned onto the same spatial dimension at each user so that the desired signal can be separated and successfully decoded. In the literature, several interference alignment strategies have been proposed for multi-cell MIMO systems, and progress has been made in designing efficient interference alignment algorithms. With interference alignment, multiple concurrent interference-free transmissions are achievable and the performance of cell-edge users can be improved.

However, since an additional spatial dimension is sacrificed for accommodating interference rather than transmitting user data, interference alignment may be outperformed by spatial multiplexing when the inter-cell interference is insignificant. Therefore, in a multi-cell system with users who experience various levels of inter-cell interference, the performance can be improved by allowing the base stations to choose between different MIMO transmission strategies.

Scheduling plays an important role in improving the system performance. For time slotted systems, where the time frame is divided into slots, in each time slot, the downlink scheduling scheme selects a set of users to be served with the objective to optimize certain performance metrics such as stability, throughput, and fairness. In the literature, several scheduling schemes have been proposed for MIMO systems under different queuing models, such as the infinitely backlogged model. The scheduling objective is to maximize the throughput or a utility function which reflects a certain fairness criterion. However, most existing scheduling schemes are designed for a single-cell scenario where inter-cell interference is not considered. The scheme in considers scheduling in the presence of inter-cell interference, but only studies a non-cooperative scenario where base stations schedule their transmissions independently without any interference mitigation technique. Joint scheduling, power allocation, and precoder design has been studied for multi-cell systems.

II. RELATED WORKS

A. Overcoming Interference In Spatial Multiplexing MIMO Cellular Networks

Multi-antenna transmission and reception (known as MIMO) is widely touted as the key technology for enabling wireless broadband services, whose widespread

success will require 10 times higher spectral efficiency than current cellular systems, at 10 times lower cost per bit. Spectrally efficient, inexpensive cellular systems are by definition densely populated and interference-limited. But spatial multiplexing MIMO systems- whose principal merit is a supposed dramatic increase in spectral efficiency- lose much of their effectiveness in high levels of interference.

This article overviews several approaches to handling interference in multicell MIMO systems. The discussion is applicable to any multi-antenna cellular network, including 802.16e/WiMAX, 3GPP (HSDPA and 3GPP LTE), and 3GPP2 (lxEVDO). We argue that many of the traditional interference management techniques have limited usefulness (or are even counterproductive) when viewed in concert with MIMO.

The problem of interference in MIMO systems is too large in scope to be handled with a single technique: in practice a combination of complementary countermeasures will be needed. We introduce a new system-level interference-reducing strategy based on cooperation, which will be important for overcoming interference in future spatial multiplexing cellular systems.

B. Interference Alignment and Degrees of Freedom of the K-User Interference Channel

For the fully connected K user wireless interference channel where the channel coefficients are time-varying and are drawn from a continuous distribution, the sum capacity is characterized as:

$$C(SNR) = \frac{K}{2} log(SNR) + log(SNR)$$

Thus, the K user time-varying interference channel almost surely has K/2 degrees of freedom. Achievability is based on the idea of interference alignment.

Examples are also provided of fully connected K user interference channels with constant (not time-varying) coefficients where the capacity is exactly achieved by interference alignment at all SNR values.

C. Cellular Interference Alignment with Imperfect Channel Knowledge

Interference alignment is evaluated as a technique to mitigate inter-cell interference in the downlink of a cellular network using OFDMA. The sum mutual information achieved by interference alignment together with a zero-forcing receiver is considered and upper and lower bounds are derived for the case of imperfect channel knowledge.

The sum mutual information achieved by interference alignment when the base stations share their information about the channels is shown to compare favourably to the achievable sum-rate of methods where the base stations do not cooperate, even under moderately accurate knowledge of the channel state.

III. PROPOSED SYSTEM

We consider a multi-cell system where each base station maintains a finite data buffer and users experience different levels of inter-cell interference. We first focus on the design and analysis of scheduling schemes with perfect CSI at the base stations, and then describe their extension to the realistic scenario of imperfect CSI.

The major contributions of this work are summarized as follows:

- We formulate an optimization problem which aims to jointly select a user and connecting the user to the tower with high signal strength. We first develop a calibrated value of signal strength and the distance between tower and the user, which is collectively termed as the RSSI value. The pre-determined RSSI value is fed to the scheduler along with the signal strength to decide as to which tower the user should be switched to.

- If the RSSI and the signal strength received from two or more towers are same, then mobile station will switch to the previous tower itself.

- To reduce the communication overhead, we propose a distributed scheduling scheme which only requires limited message exchange among the base stations. In this scheme, each base station first determines the optimal scheduling decisions for a fixed transmission strategy. Then, to arrive at the final scheduling decisions, the base stations coordinate with each other by exchanging the value of one variable.

- When the CSI is imperfect at the base stations, the data rate calculated assuming perfect CSI is not accurate and outages may occur during the transmission. To address this issue, we propose a rate adjustment scheme to improve the transmission success probability. We show that this approach improves the performance significantly compared to the case without rate adjustment.

- Simulation results show that the performance of the proposed system is better than the existing systems.
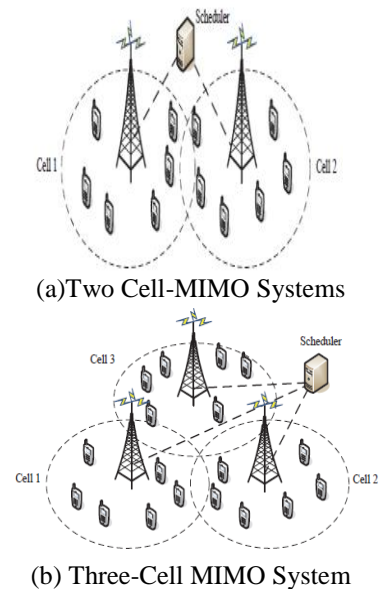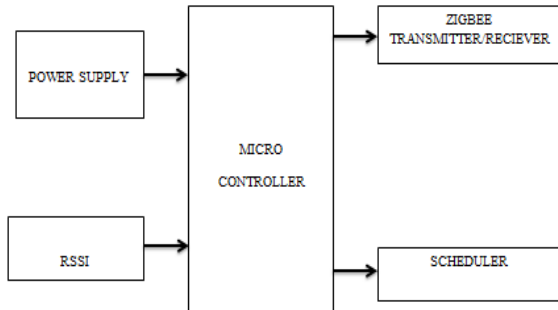

(a)Two Cell-MIMO Systems

(b) Three-Cell MIMO System

Fig.1. Multi-cell MIMO Systems (a) Two-cell case;
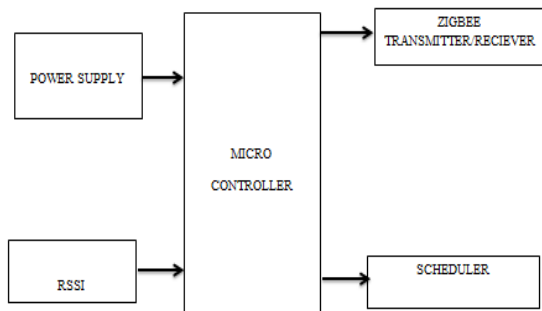(b) Three-cell case.

IV. BLOCK DIAGRAM

The block diagram of the system is given in Fig 2(a), 2(b), 2(c).

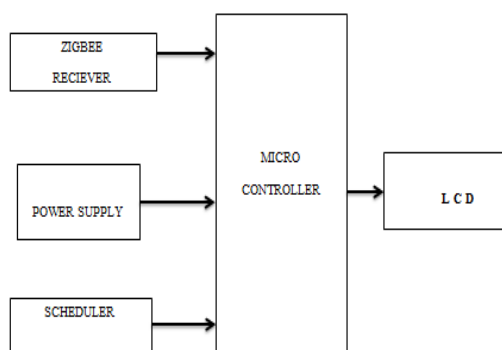Our proposed system mainly consists of three sections. They are:

a) Area1,
b) Area2 and,
c) Control station.

(a) Block diagram of Area 1

(b) Block diagram of Area 2

(c) Block diagram of Control station

Fig.2. Block diagrams of the proposed system. (a) Area1;
(b) Area2; (c) Control station

Micro controller in the transmission section is fed with the pre-determined RSSI value and is stored in the scheduler. Relative Signal Strength Indicator (RSSI) is the calibrated value of the signal strength and signal distance from the scheduler and the user. This is treated as the main feed to the micro controller IC at the control station and it compares these RSSI values from the neighbouring towers. Accordingly, the scheduler switches the user to the tower with best RSSI value. The RSSI value and the corresponding tower will be displayed in the LCD screen.

V. SOFTWARE IMPLEMENTATION

The system software was developed using the following software tools.

*   MATLAB Version 7.9 - to demonstrate the MIMO concept.
*   KEIL COMPILER – to compile the C programming.
*   PROTEUS – to design the circuit diagram of hardware portion.

Algorithm: Encoding and Decoding using LDPC method
1.   Initialization
2.   Input the data to be encoded.
3.   LDPC encoding.
4.   Parallel to series conversion of data.
5.   Interleaving of the encoded bits.
6.   Channel encoding of the encoded bits.
7.   Transmitting the data in to the AWGN channel.
8.   Channel decoding of the data received from the channel at the receiver section.
9.   De-interleaving of the decoded bits.
10. Series to parallel conversion of the de-interleaved data.
11. Connect to the tower.
12. LDPC decoding.
13. Stop.

In Algorithm, the scheduler first initializes all system parameters before the scheduling process begins. The data to be encoded is given as the input and it is then encoded by using Low Density Parity Check (LDPC) method. The encoded parallel data is then converted to series. This series data undergoes for interleaving process i.e, representing a single bit as multiple bits. After interleaving process, the data is send to the AWGN channel. The received data is then de-interleaved, thus converting the series data into parallel. LDPC decoding is done followed by transmitting the data by connecting to the tower.

VI. PERFORMANCE EVALUATION

We evaluate the performance of the proposed scheduling schemes via simulations. We first consider a two cell MIMO systems using conventional and proposed methods.
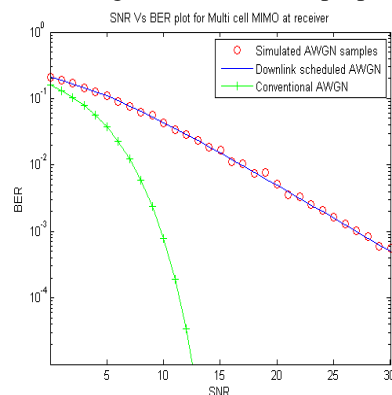

Fig.3 Graph of SNR v/s BER

We implement the proposed scheduling scheme according to Algorithm. We compare its performance with the conventional method. While plotting the signal to noise ratio (SNR) to the bit error rate (BER), we can see that in conventional and proposed method, as BER is decreasing, SNR increases. But in the conventional method, BER is approaching zero much earlier than the proposed system which leads the SNR to remain constant. For an ideal system, SNR should not be constant.

In the proposed system, BER is approaching zero very slowly so that the SNR should not remain constant as earlier like in the conventional method. Simulation results show that the performance of the proposed system achieve a better performance than the existing systems.

VII.CONCLUSION

In this paper, we designed scheduling schemes for the downlink of MIMO systems.We formulate an optimization problem which aims to jointly select a user and connecting the user to the tower with high signal strength. We developed a calibrated value of signal strength and the distance between tower and the user, which is collectively termed as the RSSI value. The pre-determined RSSI value is fed to the scheduler and is then used correspondingly with the signal strength to decide the tower which should be connected with the user.To reduce the communication overhead, we propose a distributed scheduling scheme which only requires limited message exchange among the base stations. While this work studied the multi-cell system where base stations have a common interest, it is also interesting to consider systems with selfish base stations and design energy efficient scheduling schemes. These are interesting topics for future work.

ACKNOWLEDGMENT

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