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Multi-Cell Virtual MIMO System in LTE

Mrs. Tilottama Dhake, Delzad Bajan, Milan Chheda, Akash Malusare, Sagar Ayare

Abstract- This paper is to evaluate the system level performance of LTE uplink and presents some evaluation methodologies. Joint orthogonal user grouping, proportional fairness scheduling and open loop power control are evaluated in Virtual MIMO single carrier -frequency division multiplexing access (SC-FDMA) systems. Open loop power control is proposed to use in the uplink of LTE. Simulation results show that open loop power control can improve the system throughput, lower system interference condition and satisfy the fairness criterion among users.

Index Terms- Virtual MIMO; Multi cell; LTE; scheduling; power control; throughput; uplink

1 INTRODUCTION

Orthogonal Frequency Division Multiple Access (OFDMA) has been selected as the multiple access scheme for the downlink of LTE and Single-Carrier Frequency Division Multiple-Access (SC-FDMA) for the uplink [1]. OFDM is an attractive modulation technique in a cellular environment, because of its capability to enable low complexity multipath channel mitigation. At reduced Peak-to-Average Power Ratio (PAPR), SC-FDMA can achieve a performance comparable to OFDM for the same complexity. The performance of SC-FDMA can be further improved by using a MMSE (Minimum Mean Square Error) equalization receiver [2]. The choice of transmission is DFT-Spread OFDM (DFT-S OFDM). Here, user data symbols in time domain are changed to frequency domain by a Discrete Fourier Transform (DFT) and spread by inserting zero symbols before going through IFFT modulation so that orthogonality in frequency domain can be obtained among users in uplink and the receiver side can get effective frequency domain equalizer (FDE).

In uplink, every terminal has only one transmit antenna. Virtual MIMO has been adopted for uplink data transmission in order to make complete use of MIMO (Multiple-Input-Multiple-Output) spatial multiplexing. In case of Virtual MIMO, different users can share the same time-frequency resource, which forms a user group. Data information of various users in the same group is multiplexed onto the same time-frequency resource and can be detected in the base station (BS). Thus the user group and BS can make up of spatial multiplexing MIMO on the condition that the number of users in one group is not larger than that of the receiving antenna equipped in BS [3].

Power control can mitigate the near-far effect deriving from the existence of intra-cell interference. In LTE system, the inter-cell interference causes severe degradation of system performance, particularly for the cell edge users. Therefore, the role of power control is to adapt power to path loss and shadow fading fluctuations and decrease the other cell interference [4].

However, the uplink of LTE system introduces some new problems to system level evaluation especially for the adoption of Virtual MIMO, unlike the previous 3G CDMA systems, whose evaluation methodologies are mature enough and have been widely agreed on.

This paper is to study the system level performance of LTE uplink and presents some evaluation methodologies of system level simulation. Signal-to-noise ratio, bit error rate, throughput and open loop power control are evaluated in Virtual MIMO SC-FDMA systems through the system level simulation.

The rest of this paper is organized as follows. SC-FDMA and Virtual MIMO system models are shown in Section I. In Section II, the proposed power control for LTE uplink is given in detail. In section III, the performance of this scheme is presented via system level simulation. Finally, we give conclusions in Section IV.

2 SYSTEM MODEL IN UPLINK OF LTE

The uplink of LTE cellular system with M subcarriers is considered in this paper. Virtual MIMO and SC-FDMA are used to improve the system throughput and reduce the PAPR and DFT-S OFDM is the choice of SC-FDMA. In DFT-S OFDM, user data symbols are firstly transformed to frequency domain by DFT and spread by inserting zero symbols before going through IFFT modulation and the receiver side can get effective FDE.

Every user has one transmit antenna, and NR receiving antennas are assumed to be equipped in BS. In Virtual MIMO, a number of users in the same cell can compose of a user group, where these users can share the same time-frequency resource. We denote N as the number of users in the same group. Therefore, these N users in the same group and their serving BS can make up of NR×N spatial multiplexing MIMO on the condition that $NR \geq N$, which can improve uplink throughput. An NR×N Virtual MIMO is illustrated in Fig 1.

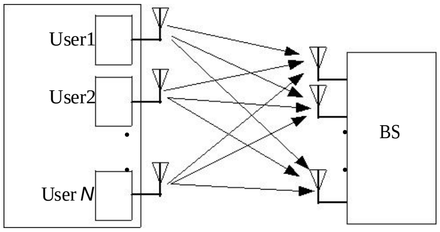

Fig 1. Structure of $N_R \times N$ Virtual MIMO

As shown in Fig. 1, user 1, 2, …, and N are in the same cell and compose of user group A. Each user has one transmit antenna, and NR receiving antennas are equipped in BS s. In a multi-cell virtual MIMO-OFDMA system, every user suffers from both intra-cell interference and inter-cell interference due to use the same subcarrier simultaneously. We can use MMSE equalizer to distinguish the useful signal of each user at base station.

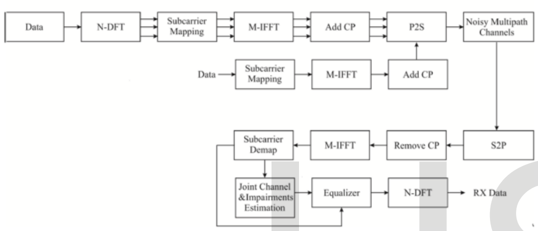

Fig 2. Block Diagram of SC-FDMA

Fig. 2 shows the basic working of the proposed SC-FDMA. The input data is N length and M number of random signal, which is multi-user, where N=100,1000…. and M=1,2…

This signal encoded by convolutionally encoded first. After encoding, the encoded data is modulated using QAM/PSK. This data is converted from frequency domain to time domain using IFFT. Here we are adding cyclic prefix to avoid ISI (Inter Symbol Interference) and ICI (Inter carrier interference). After adding CP, the data is transmitted using a channel with noise.

At receiver, a zero forcing equalizer is applied, which corresponds to bringing down the inter symbol interference (ISI) to zero. A zero forcing equalizer refers to a form of linear equalization algorithm used in communication systems which applies the inverse of the frequency response of the channel. After this, CP can be removed, and the data can be transformed to frequency domain, after which demodulation and decoding is performed for recovering data.

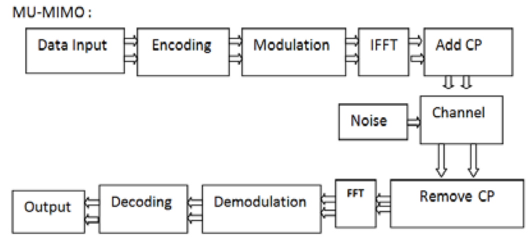

Fig 3. Block Diagram of MU-MIMO

The above block diagram shows the flow of MU-MIMO working. This is similar to the earlier mentioned SC-FDMA, but involves multiple data input.

3 OPEN LOOP POWER CONTROL SCHEME

In LTE system, uplink power control is used to compensate for the path loss and shadow fading fluctuations in open loop mode combining the close loop feedback, which can successfully reduce the other-cell interference with lower complexity[5]. Meanwhile, the serving base station sends cell wide overload indicator (OI) and a high interference indicator (HII) to control the uplink interference according to the interference situation [6].

In this paper, one open loop slow power control scheme is proposed as follows. For simplicity, the target SINR should be set as a function of the path loss difference between the serving cell and the strongest neighbouring cell:

$$\begin{aligned} SINR_{target} &= \gamma + (1-\alpha).\Delta Pathloss \\ &= \gamma + (1-\alpha).(Pathloss\_q - Pathloss\_s) \end{aligned} \quad \text{------(1)}$$

where $Pathloss\_q$ and $Pathloss\_s$ are the path loss (including shadowing) of the user to its strongest neighbouring cell and to its current serving cell, respectively. This measurement is made by computing the ratio of the received downlink pilot power measurements is the compensating factor to compensate the path loss difference is a parameter to adjust the target SINR value.

Therefore, the user transmit power spectrum density (PSD) is calculated using equation (2),

$$\begin{aligned} TxPSD &= SINR_{target} + Pathloss\_s \\ &= \gamma + (1-\alpha).(Pathloss\_q + Pathloss\_s) \end{aligned} \quad \text{------(2)}$$

Interference over thermal noise (IoT) is generally used to evaluate the interference condition in uplink. IoT is defined as,

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$$IoT = \frac{I+N_0}{N_0} \quad \text{------(3)}$$

where, N0 is the thermal noise and I is the total received interference on all the subcarrier clusters.

4 System Level Simulation and Results

In order to simulate and evaluate the performance of the proposed scheduling and power control scheme in the uplink of multi-user MIMO-OFDMA cellular system, an LTE system level simulation platform is established. We consider a scenario where each user undergoes fast fading and large-scale fading. The fast fading of users can be generated via SCME Model [7]. The propagation model can be given by PL=128.1+37.6lg(R), where R in kilometer, is the distance between the BS and the user. The shadowing fading is lognormal distribution with mean 0 and standard derivative 8 dB, and the correlation distance is 50m.

In order to assess the system performance gain we simulate the average sector throughput with and without open-loop power control (OLPC) in uplink.

Table 1. Main system simulation parameters

Parameters	Values
Carrier frequency	2 GHz
System bandwidth	10 MHz
Neighboring subcarrier spacing	15 KHz
Number of available subcarriers	600
Number of clusters	50
Number of subcarriers per cluster	12
Scheduling period	1ms
User distribution	Uniformly
Inter-site distance	500m
User maximal Tx power	24 dBm (250mw)
MIMO configuration	2×2, Virtual MIMO
User speed	3Km/h
HARQ	Chase combining
Simulation duration	10s
Site layout	7 cells, 3 sectors per cell

As shown in Table 2, we can see that adopting OLPC can obtain better performance gain in terms of average throughput and spectrum efficiency. If there is no power control, system IoT is very large, especially for the smaller inter-site distance. The IoT distributions of two schemes are shown in Fig 4.

Table 2. Comparison of no PC and OLPC

Power control	Average sector throughput (Mbps)	Average sector spectrum efficiency (bps/Hz)	IoT mean (dB)	IoT standard derivation (dB)
No PC	2.798	0.28	28.89	3.967
OLPC	5.626	0.56	15.59	5.448

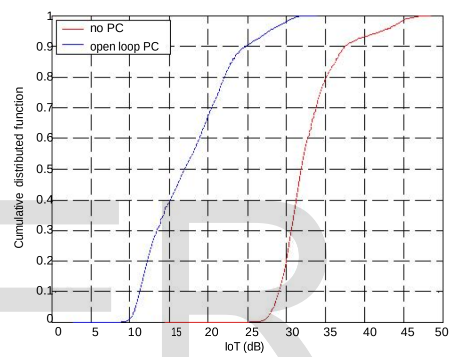

Fig 4. IoT distributions of no PC and OLPC

5 Conclusions

This paper was therefore written to evaluate and simulate the system level performance of LTE uplink and presents some evaluation methodologies. Joint orthogonal user grouping, proportional fairness scheduling and one open loop power control scheme were evaluated in virtual MIMO SC-FDMA systems. Simulation results show that open loop power control(OLPC) improves the system throughput, lowers system interference condition and satisfies the fairness criterion among users.

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