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Combined Detection of ZF and Partial ML for Uplink Cellular BS Cooperation

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Abstract. In this paper, we address the issue of joint detection schemes for uplink cellular system when base station cooperation is possible for multi-cell users in multi-cell scenario. The ZF and ZF based SIC detection are analyzed and evaluated, however, they need the increased decoder complexity as the number of iteration is increased. We propose a new joint ZF and partial ML decoding scheme, which combines the ZF detection and partial ML decoding scheme in order to improve the detection performance and also decrease the decoder complexity. Simulation results show that the proposed scheme attains the better BER performance and also provide a much reduced decoder complexity The proposed scheme can be applied to the MIMO detection for single user and can be extended to multi-user and multi-antenna based other types of BS Cooperation.

Keywords: MIMO detection, ML, ZF/MMSE, SIC, Base Station Cooperation

1 Introduction

The capacity of today's cellular mobile communication systems is mainly limited by inter-cell interference, which is the interference from neighboring cells. The solution to overcome this limitation, one possible option to mitigate this kind of interference is the multi-cell joint detection, which are based on the neighboring BS cooperation and it means that the neighboring signal across cell edge can be utilized rather than treating as interference. [1]

MIMO detection for single user and multiple antennas can be considered as the joint detection scheme. [2] Traditional Maximum Likelihood (ML) detection can be used for optimal decoding, but the decoder complexity make its practical application be impossible. Therefore, a low complexity receiver such as Zero-Forcing with Successive Interference Cancellation (ZF-SIC) was proposed (see [3]).

In this paper, we propose the new detection scheme which can provide both the better BER performance and the reduced complexity compared with joint ZF based SIC detection scheme. The proposed scheme combines the linear ZF detection and the

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partial ML decoding concept to increase the reliability of the first decoded symbol, which can avoid the following error propagation effect to next step.

Simulation Results show that the proposed scheme attains the a little bit better BER performance and similar or reduced complexity over the ZF based SIC scheme in various scenarios of the involving mobile stations in uplink multiple cellular communication

2 System Model

We consider an uplink transmission from M terminals (UEs) with one antenna each to N base stations (BSs) with one antenna. We can state the received N vector $\mathbf{r} = [r_1, r_2, \cdots, r_N]^T$ is corresponded to the transmitted vector $\mathbf{s} = [s_1, s_2, \cdots, s_M]^T$ can be represented as

$$\mathbf{r} = \mathbf{Hs} + \mathbf{n} \tag{1}$$

,where $\mathbf{r} \in \mathbf{C}^{[N \times 1]}$ are the signals received at the BSs, $\mathbf{H} \in \mathbf{C}^{[N \times M]}$ is the channel matrix, $\mathbf{s} \in \mathbf{C}^{[M \times 1]}$ are the symbols transmitted from the UEs, and $\mathbf{n} \in \mathbf{C}^{[N \times 1]}$ is the complex Gaussian noise vector with zero mean and unit variance.

The channel matrix $\mathbf{H}$ can be described as

$$\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1M} \\ h_{21} & h_{22} & \cdots & h_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ h_{N1} & h_{N2} & \cdots & h_{NM} \end{bmatrix} \tag{2}$$

where h_{ij} represents the channel gain from transmitted UE j to received BS i.

3 Joint ZF and Partial ML Detection

In this section, in order to reduce the decoder complexity and to increase the reliability of the first decoded symbol in successive decoding operation, we propose a new joint ZF and partial ML detection scheme, which calculate the inverse matrix only once and apply the partial ML decoding for other remaining symbols to be detected more reliably.

The details of the proposed scheme is depicted as follows.

Step 1. Initial Detection by ZF Decoding and determine $\overline{\mathbf{s}}$ as the reference signal for next partial ML decoding.

$$\overline{\mathbf{s}} = (\mathbf{H}^H \mathbf{H})^{-1} \mathbf{H}^H \times \mathbf{r} \tag{10}$$

Step 2. Decide the order of decoding by descending order of the received SINR (Signal to Interference and Noise Ratio) of the received symbol vector $\mathbf{r}_i$.

$$SINR_{\mathbf{r}_i} = \frac{\left\| h_{ii} \right\|^2}{\sigma_n{}^2 + \sum_{\substack{j=1 \\ j \neq i}}^{M} \left\| h_{ij} \right\|^2} \tag{11}$$

where $\sigma_n{}^2$ is the variance of the Gaussian noise vector.

Step 3. Apply the partial ML decoding only to the first symbol vector, which results from the determination of decoding order in step 2, when other symbol vectors except the first decoding symbol vector have the fixed value, which are already determined by initial ZF Decoding in Step 1. For example, if we assume the first decoding symbol is $\tilde{\mathbf{s}}_1$, the remaining initial $\bar{\mathbf{s}}$ vectors, $\bar{\mathbf{s}}_2, \bar{\mathbf{s}}_3, \cdots, \bar{\mathbf{s}}_M$, can be determined from the decoding results from Step 1 and then apply the partial ML decoding only for $\mathbf{s}_1$ in order to get , $\hat{\mathbf{s}}_{1,ML}$, which will results the first decoded symbol vector from partially applied ML detection and this results can be utilized to next step for next iterative decoding operation.

$$\hat{\mathbf{s}}_{1,ML} = \arg\min_{\tilde{\mathbf{s}}_1 \in \gamma} \left\| \begin{bmatrix} \mathbf{r}_1 \\ \mathbf{r}_2 \\ \vdots \\ \mathbf{r}_N \end{bmatrix} - \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1M} \\ h_{21} & h_{21} & \cdots & h_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ h_{N1} & h_{N2} & \cdots & h_{NM} \end{bmatrix} \begin{bmatrix} \tilde{\mathbf{s}}_1 \\ \bar{\mathbf{s}}_2 \\ \vdots \\ \bar{\mathbf{s}}_M \end{bmatrix} \right\| \tag{12}$$

Step 4. Repeat partial ML Decoding operation in Step 3 in the same manner to other remaining symbol vector $\mathbf{s}$ according to the decoding order in Step 2 until all the values of symbol vector $\mathbf{s}$ are finally recovered

4 Simulation Results

In this section we present some numerical results and the comparisons of BER performances of proposed & conventional detection schemes for various scenarios.

Some physical layer parameters of target system and most of them are in line with IEEE 802.16m EMD documents [4] and we produce the sample data based on these system parameters. As a noise and interference model, AWGN (Additive White Gaussian Noise), path loss due to the distance between BS and MS and Rayleigh flat multi-path fading are assumed in this paper [5].

We assume Cell Edge scenario, which means that the distance between BS and MS is more than 80 % of cell radius, hence, this assumption corresponds to nearly one of the worst case scenario for the locations of the involved BS and MS in multi-cellular communication.

Fig. 1 represents the BER performance comparison between proposed scheme and conventional detection algorithms. Fig. 3 and Fig. 4 compare the BER performances of ZF, ZF-SIC and proposed scheme for two different cases, which is the number of cooperative Base Stations is 3 and 4, respectively.

No joint Detection means that no cooperation is made between neighboring Base Stations. The proposed scheme attains nearly 4 ~5 dB reduced required SNR value over ZF and 1.5 ~ 2dB reduced required SNR value over ZF-SIC scheme in order to achieve the same BER performance.

These figures show that the Base Station Cooperation seems to be imperative to guarantee the minimum detection performance in some range of cell border.

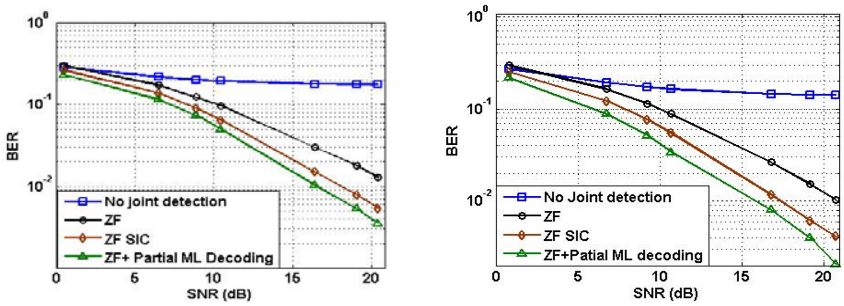

Fig. 1. BER performance comparison of joint detection algorithms when Three and four BSs are cooperated.

5 Conclusion

In this paper, we investigated the uplink joint detection techniques for uplink cellular system when base station cooperation is possible in multi-cell scenario.

A new joint ZF and partial ML detection scheme was proposed to reduce the decoder complexity and also to improve the detection performance of multi-cell based multiple received signals. Simulation results show that the proposed scheme attains the improved BER performance over ZF and ZF based SIC scheme and also additionally achieves much reduced decoder complexity as the number of BS cooperation is increased since it does not need to compute inverse matrix operation in each stage.

References

1. P. Marsch, G. Fettweis , On Uplink Network MIMO under a Constrained Backhaul and Imperfect Channel Knowledge”, IEEE International Conference on Communication (ICC) (2009)
2. A. Goldsmith, S. A. Jafar, N. Jindal, and S. Vishwanath, “Capacity Limits of MIMO Channels, IEEE Journal on Selected Areas in Communications”, Vol. 21, No. 5, pp. 684-702, June (2003)
3. G. Wang, D. Wang and D. Li, “An Efficient ZF-SIC Detection Algorithm in MIMO CDMA System”, The 14th IEEE 2003 PIMRC, Vol. 1, pp. 1708-1711, (2003)
4. IEEE 802.16m Standardization Group, "802.16m Evaluation Methodology Document", v. 1.0, Jan. (2009)
5. S. Cai, Z. Duan and J. Gao, “Comparison of Different Virtual MIMO Detection Schemes for 3GPP LTE”, IEEE 5th WiCom, pp. 1-5, (2009) September