A Novel method for Inter-Cell Interference Cancelation in Cellular Networks

Shuo Yang, Kyunghoon Kim, Heungseop Ahn, and Seungwon Choi
Electronics and Computer and Engineering Department, Hanyang university, Seoul, Korea
{yangshuo, kkh0602, ahs90, choi}@dsplab.hanyang.ac.kr

Abstract **– This paper proposes a novel transmission technique for Inter-Cell Interference Cancelation (ICIC) in cellular networks. The new technique utilizes the Conjugate Gradient Method (CGM) for calculating the optimal weight vector for the transmitting antenna array system operating at a base station. The weight vector provides a maximum gain along the direction of a target mobile device and deep nulls to the directions of the other mobile devices in neighboring cells. While conventional ICIC methods using Zero Forcing (ZF) algorithm [1] suffers from the problem of obtaining Channel State Information (CSI) associated with the neighboring cells, the proposed method is absolutely free from the unrealistic assumption of the availability of the CSI. Simulation results show that sum-rate of the proposed method is superior to that of conventional method.**

Index Terms **— Conjugate Gradient Method, Zero Forcing Beamforming, Inter-Cell Interference Cancelation, Sum-rate.**

1. Introduction

In present cellular system, inter-cell interference is a serious problem that limits the system performance. To improve the system sum-rate, Inter-Cell Interference Cancelation (ICIC) is a key technique that nulls the unwanted direction in neighboring cells. Conventional ICIC methods using Zero Forcing (ZF) algorithm [1] is valid under an assumption that the target BS is able to obtain the Channel State Information (CSI) of unwanted direction in the other neighboring cells. We propose a novel technique adopting the Conjugate Gradient Method (CGM), which can solve the problem without the unrealistic assumption. Through the various computer simulations, we have found that the system sum-rate of the proposed method is superior to that of the conventional method.

2. System Model

In this paper, we consider a cellular network that has B cells which are indexed as $j=1,\ldots,B$. Each of cell has one BS setting up with $2L-1$ antennas, and each of mobile user has a single antenna. Fig. 1 shows a downlink system and 3-cell network.

Here, we use a narrow-band flat-fading channel model. The received signal of mobile user i at time-slot n from BSs is expressed as follows.

$$r_i[n]=\sqrt{p_{i,i}}\,h_{i,i}^H[n]x_i[n]+\sum_{j=1,j\neq i}^{B}\sqrt{p_{i,j}}\,h_{i,j}^H[n]x_j[n]+z_i[n] \qquad (1)$$

where we assume that each of BS j serves only one mobile user in its own cell j while causing intercell interference to the neighboring cells. We denote that user i and BS i for $i=j, i=1,\ldots,B$ when the user i and BS j are in the same cell. $h_{i,i}$ the desired channel vector that user i and BS i are in the same cell. And the interference channel vector, $h_{i,j}$ for $i\neq j, j=1,\ldots,B$, is between user i and BS j. $p_{i,j}$ is denoted distant dependent path loss and antenna gain between user i and BS j [1]. And z is the Additive White Gaussian Noise (AWGN) sample and distributed as $\mathcal{CN}(0,1)$.

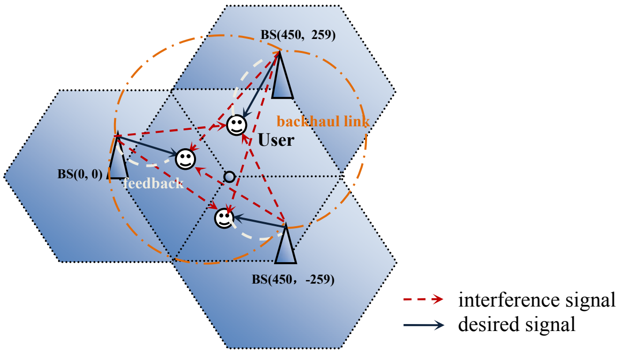

Fig. 1. An example of a 3-cell network.

3. Proposed Method

In this paper, we propose a novel transmission technique for ICIC adopting the CGM in cellular networks. The CGM is used for calculating the optimum weights vector for the transmitting antenna array system operating at a base station [2].

First, we define the position coordinates of the BSs and the mobile users. The position coordinate of user i is (a_i, b_i). The feedback is from the mobile user to its serving BS in cell, and the backhaul link connects between two neighbor cells.

Then, the channel matrix for a linear array is formed as follows [3]

$$A=\begin{bmatrix} y_1 & \cdots & y_l \\ y_2 & \cdots & y_{l+1} \\ \vdots & \ddots & \vdots \\ y_l & \cdots & y_{2L-1} \end{bmatrix} \qquad (2)$$

where we can form the channel matrix, A, when the BS through feedback obtains the angle of desired user direction and the angles of the unwanted direction of the other mobile devices in neighboring cells. y_l can be defined as

$$y_l = e^{-(l-1)j\pi\sin\theta_0} + \sum_{k=1}^{K} e^{-(l-1)j\pi\sin\theta_k}, l = 1,\ldots,2L-1 \tag{3}$$

where θ_0 is the angle of desired user direction, θ_k is the angle of k^{th} interference direction.

Finally, we can obtain the weight vector in each BS through the CGM algorithm by solving following (4)

$$Aw = d, \tag{4}$$

where Note that the channel matrix, A, is obtained at the antenna array. d is made from the angle of the desired user direction. w is the optimum weights vector which calculated by the CGM algorithm.

4. Achievable the Throughput with Delayed CSI

We calculate the sum-rate of the proposed method with different delay values through feedback and backhaul links. The delayed CSI means that the angles are transmitted through feedback and backhaul link existing time delay.

When the mobile user speed is v km/h and delay time is D, the distance of user movement is $s = vD$. φ is the angle of the direction of movement and has uniform distribution between 0° and 360°.

After the mobile user move, the position coordinates of user i is $(a_i + s\cos\varphi, b_i + s\sin\varphi)$. We could calculate degree of angles between mobile user i and BS and obtain the channel vector $h[n+D]$ when the delayed value is D.

We calculate the average sum-rate of the proposed method of formula as

$$R_{ave} = \frac{1}{B}\sum_{i=1}^{B} E[\log_2^{1+SINR_i}], i = 1,\ldots,B. \tag{5}$$

In (5), R_{ave} is assumed the average sum-rate of users. In addition, the signal-interference-plus-noise ratio (SINR) for the mobile user i denotes $SINR_i$ that is calculated as,

$$SINR_i = \frac{p_{i,i}\left\|h_{i,i}^H[n+D]w_i[n]\right\|^2}{1+\sum_{j=1,j\neq i}^{B} p_{i,j}\left\|h_{i,j}^H[n+D]w_j[n]\right\|^2} \tag{6}$$

where

$$D = \begin{cases} D_{fb} & if\ i = j \\ D_{fb} + D_{bh} & if\ i \neq j \end{cases} \tag{7}$$

and $p_{i,i}\left\|h_{i,i}^H[n+D]w_i[n]\right\|^2$ is the desired signal power. $\sum_{j=1,j\neq i}^{B} p_{i,j}\left\|h_{i,j}^H[n+D]w_j[n]\right\|^2$ is the interference power from neighboring cell j. w_j denotes the weight vector from the adjacent BSs. D_{fb} is the delayed value of feedback and D_{bh} is the delayed value of backhaul link between BS and BS.

5. Simulation Results and Analysis

We set $B = 3$, $v = 15$ km/h and the radius of cell $C = 300$ m. The number of antennas is 7. In Fig. 2, the system sum-rate of the proposed ICIC method adopting the CGM algorithm is compared with that of conventional method [1].

When $D_{fb} = D_{bh} = 0$ ms, it means that the CSI delay through feedback and backhaul links is not considered. So this situation does not exist in real life. When $D_{fb} = 5$ ms and $D_{bh} = 8$ ms, the sum-rate of proposed ICIC method is 8.42 bps/Hz at the distance 150 m. The sum-rate is more than 2.5 bps/Hz comparing with the conventional ICIC methods [1]. Even if the CSI delayed, the beamforming gain of proposed ICIC method is reduced very small. Thus, the sum-rate has no change. We have found that the system sum-rate of the proposed method is superior to that of the conventional method [1].

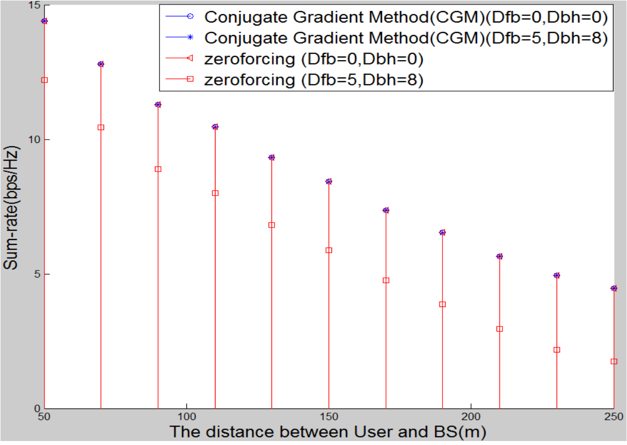

Fig. 2. The average sum-rate of 3 mobile users under different delayed values.

6. Conclusion

In this paper, we propose a novel technique adopting the CGM comparing with the conventional method [1], which can solve the problem without the unrealistic assumption. Through the various computer simulations, we have found that the system sum-rate of the proposed method is superior to that of the conventional method [1]. Therefore, the method adopting the CGM is suitable for ICIC in cellular network systems.

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