Adaptive Beamforming with Per-Antenna Feedback for Cooperative MIMO Systems

Sungmoon Chung[1], Inwhee Joe[2]
,

[1] Department of Electronics and Computer Engineering, Hanyang University, Seoul, Korea
[2]Division of Computer Science and Engineering, Hanyang University, Seoul, Korea
iwjoe@hanyang.ac.kr

Abstract. We propose a new adaptive user antenna beamforming method for cellular systems which simultaneously communicates with multiple available BSs and RSs using the MS's multiple antennas. We show that the proposed beamforming system outperforms conventional beamforming system by increasing the data rate.

Keywords: Beamforming, MIMO, Cooperative, feedback.

1   Introduction

The beamforming technique is used in MIMO systems to improve link reliability using interference rejection and linear combining . Most of   beamforming techniques [1][2][3] select BS or RS which has the strongest signal strength by MS (Mobile Station) and exchange of feedback information with BS or RS. As a result, MS can communicate only one BS or RS simultaneously. So that they can't use spatial multiplexing when the antennas of MS aren't spaced sufficiently. Distributed transmit beamforming [4] is a form of cooperative communications in which two or more information sources simultaneously transmit a common message and control the phase of their transmissions so that the signals constructively combine at an intended destination. However it is difficult to use practically because the sources must do information sharing and strict timing synchronization when they send same data. Also Distributed transmit beamforming can't use spatial multiplexing because sources send same data.

Our proposed beamforming system can use available BS or RS simultaneously using MS's multiple antennas. Therefore available BS or RS send independent data and it can improve performance of user's data rate with less degradation of the BER.

2   Adaptive Beamforming with Per-Antenna Feedback

Figure 1 shows our proposed beamforming algorithm. When the MS enters the overlapped area, the MS receives a beacon message to scan for BSs and RSs. MS

send its CSI and data query message which indicate desired data information to BSs or RSs. And the BSs or RSs send the feedback information to their CP (Central Process), CP checks the CSI in order to determine any CQI (Channel Quality Indicator) of CSI is greater than the threshold and make feedback including estimated CSI. Those below threshold are reduced because that would decrease the BER efficiency. Then CP allocates required data to available BSs or RSs according to CSI. After available BSs or RSs are scheduled by CP, they send independent data to each antenna of MS. The number of BSs and RSs that communicate simultaneously is dependent on the MS's multiple antennas and the number of available BSs and RSs. MS can use spatial multiplexing when there are the same or more number of available BSs and RSs than number of MS's antenna. Therefore, our proposed system can send independent data from available BSs and RSs to the antenna of the MS.
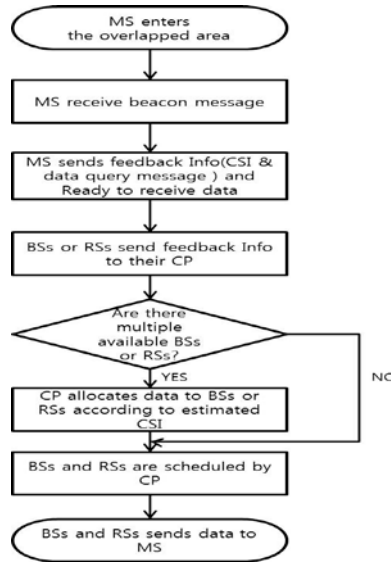

Figure. 1. Proposed beamforming algorithm

3   Performance Evaluation

We tested our proposed beamforming system, setting the number of available BSs or RSs to 4 and setting signal strengths to 10, 9, 8, and 7 dB (0dB=1Vrms), respectively. These levels were set through feedback information exchanged between the MS and each available BS or RS. An MS cannot have many antennas due to its size. Therefore we assume that the number of antennas in the MS varied from 2 to 4. Distributed transmit beamforming selects the multiple BSs or RSs. But its sources can transmit a common message at a time, and its channel capacity can be calculated with Equation (1).

Distributed transmit beamforming:

$$C = W^* F_{BF} * log_2(1 + \frac{n_t P}{\sigma^2}|h|^2) \quad [5] \tag{1}$$

Here, W is bandwidth, F_{BF} is the frequency reuse ratio in a cell, and P is transmit power. Our proposed beamforming system can simultaneously use multiple available BSs or RSs using the MS's multiple antennas, and its channel capacity can be calculated with Equations (2),(3).

Proposed beamforming with two antennas:

$$C = W^* F_{BF} * \{log_2\left(1 + \frac{n_{t1}P_1}{\sigma_1^2}|h_1|^2\right) + log_2\left(1 + \frac{n_{t2}P_2}{\sigma_2^2}|h_2|^2\right)\} \tag{2}$$

Proposed beamforming with one Mr antenna:

$$C = W^* F_{BF} \sum_{n=1}^{M_r} log_2(1 + \frac{n_{tn}P_n}{\sigma_n^2}|h_n|^2) \tag{3}$$

Data rate per bandwidth can be calculated with Equations (2),(3) for $F_{BF} = 4$. Figure 2 shows that our proposed beamforming system outperforms distributed transmit beamforming with respect to data rate, and the more antennas in the MS, the higher data rate is the achieved.
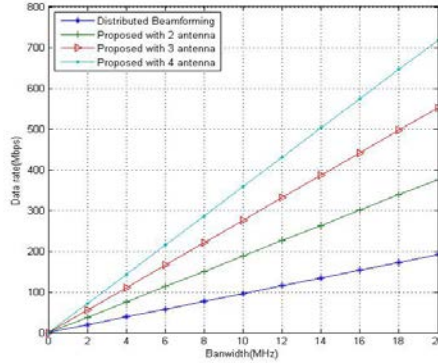

Fig. 2. Data rate per bandwidth

Table 1. Bit error rate at N=4.

Distributed Beamforming	Proposed with 2	Proposed with 3	Proposed with 4
0.0033	0.0069	0.0081	0.0089

Table 1 shows the BER performance of a beamforming system based on Equation (4) [6] in the codebook [3](N=4).

$$P_e = \int_{-\infty}^{\infty} P_e(\gamma) f_{\gamma max}(\gamma) d\gamma \tag{4}$$

$$= \frac{a}{2(2\pi)^N} * \int_{-\infty}^{\infty} \dots \int_{-\infty}^{\infty} \det(I - SI)^{-1} \prod_{m=1}^{N}(jt_m)^{-1} * \left\{ 1 + \sum_{m=1}^{n}(-1)^m \sum_{b_1 + \dots + b_N = m} \sqrt{\frac{c}{c + jb_T}} \right\} dt_1 \dots dt_N$$

Some degradation of the BER will occur in the proposed beamforming system due to the use of multiple beams. However, this degradation is small if the differences among SNR of the beams are not significant. In Table 1, all the systems have about $10^{-2} \sim 10^{-3}$ BER performance. This notice us the importance of the chosen SNR threshold that determines available BSs or RSs.

4   Conclusions

Our proposed beamforming system allows for simultaneous communication by independent beam with multiple available BSs or RSs using the MS's multiple antennas. As a result, we can use spatial multiplexing when the antenna of MS isn't spaced sufficiently. Therefore, it improves performance by increasing the user's data rate with less degradation of the BER.

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