LTE-A 시스템에서 3 차원 빔포밍 기법 연구

지형주, 심병효
서울대학교
hyoungjuji@islab.snu.ac.kr, bshim@snu.ac.kr

Three-dimensional beamforming techniques for LTE-A systems

Hyoungju Ji, Byonghyo Shim
Seoul National University

Abstract

LTE-Advanced system has been deployed with 2 and 4 transmission antennas (Tx) while the specification supports up to 8Tx. Due to deployment space, antenna dimension and complexity, the needs of deploying 8Tx system has not been motivated by operators. Recently, three dimensional (3D) beam-forming with active antenna has attracted significant attention in the wireless industry. By incorporating 2D active array into LTE-A systems, the system offers freedom in controlling radiation on elevation and horizontal dimension. When the number of antennas increases in the form of 2D arrangement, spatial separation can be realized simultaneously in horizontal and elevation domain and vertical beam-steering can increase SINR of UEs in high floors. In this paper, we study the system operations and implementations for supporting 3D beamforming with 8Tx antennas. In our schemes, by reusing the conventional CSI feedback framework, the system can operate 2D active array without harming the backward compatibility. Evaluation results show that 3D beamforming provides capacity boosting over the conventional 2D beamforming systems while keeping same antenna structure.

1. Introduction

In recent years, the wireless industry has witnessed a drastic increase of wireless data traffic on a global scale [1]. In response to the increasing demand for data traffic, 3rd Generation Partnership Project (3GPP) has initiated new standardization effort to provide cutting-edge techniques with an aim to improve spectral efficiency and user experience. Among many features studied in the 3GPP for long-term-evolution advanced (LTE-A) systems, multi-input multi-output system (MIMO) system has been recognized as one of key technology to enhance the spectral efficiency [2]. For the next step of MIMO enhancements, full dimension MIMO (FD-MIMO) has received much attention in recent year to support up to 64 antennas placed in a 2D array structure [3].

Notwithstanding the rosy prospect, it is in practical not easy to deploy 8Tx antennas for various reasons. One of the key reason is the deployment space and antenna size. At the first stage of LTE deployment, most of operations have focused on 2 or 4 antennas in the eNB side. When the cross-polarization antenna is used, the required deployment space in the transmitter tower for GSM, WCDMA, and LTE systems is more or less similar. 8Tx antenna systems do not provide attractive beamforming gain in dense urban scenario while offering substantial cost for doubling backhaul capacity.

Motivated by active antenna technology, 8Tx systems can utilize multiple antennas placed in a 2D antenna array panel to realize 2-by-4 and 4-by-2 configurations without increasing total number of antenna elements. In contrast to the passive antennas placed in a linear array, the antennas are placed in 2D planer array and further they are comprised with active radiation components. 2D 8Tx eNB has distinctive feature over the legacy MIMO systems. The transceiver units can be placed in 2D antenna array panel to enable 3D beamforming without harming the backward compatibility.

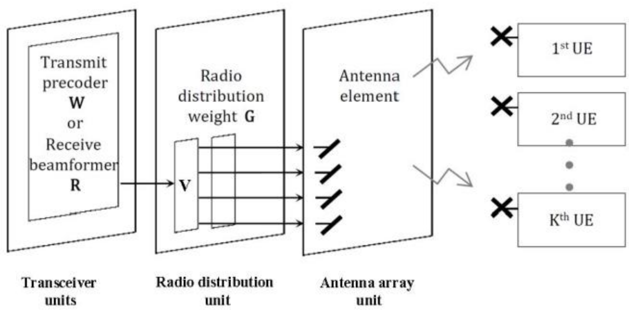

Fig. 1. System model for 2D active array

2. System Model

We consider FDD-based SU/MU-MIMO system as shown in Fig. 2. We assume that the eNB has N_T (=$N_V \times N_H$) transceiver which are placed in M_T (=$M_V \times M_H$) antenna elements. Consider a system with N_T transmit antennas at eNB, K co-scheduled UEs with precoding weight $\mathbf{W}$, the received signal $\mathbf{y}$ for the kth UE can be derived as

$$\mathbf{y}_k = \underbrace{\sqrt{\frac{P_{DL}}{N_T K}}\mathbf{H}_k\mathbf{G}_k\mathbf{W}_k\mathbf{x}_k}_{\text{Desired signal}} + \underbrace{\sqrt{\frac{P_{DL}}{N_T K}}\sum_{l\neq k}\mathbf{H}_k\mathbf{G}_l\mathbf{W}_l\mathbf{x}_l}_{\text{MU interference}} + \mathbf{n_k} \quad (1)$$

where P_{DL}, $\mathrm{H_K} \in \mathbb{C}^{N_R \times M_T}$, $\mathrm{W_K} \in \mathbb{C}^{N_T \times r}$, $\mathrm{s_k}$, $\mathrm{n_k}$ ~ $CN(0, \sigma^2 I)$ denote downlink transmission power, channel matrix between the eNB and kth UE, user-specific beamforming matrix with rank r, transmit signal for the kth downlink user with $E\{|x_k|^2\}=1$ and the additive complex Gaussian noise with zero mean and variance N_0, respectively. The radio distribution weight $\mathrm{G_k} \in \mathbb{C}^{M_T \times N_T}$, representing the relationship between the transceiver to the antenna element, is expressed as

$$\mathbf{W_T} = \begin{bmatrix} \mathbf{V} & 0 & \cdots & 0 \\ 0 & \mathbf{V} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \mathbf{V} \end{bmatrix}, \mathbf{V} = \left[v_0, v_1, \ldots, v_{N_T/N_{TXRU}}\right]^T \quad (2)$$

$$v_i = \frac{1}{\sqrt{N_T/N_{TXRU}}} exp\left(-j\frac{2\pi}{\lambda}(i-1)\, d_v\, cos\theta_t\right) \quad (3)$$

where i = 1, ..., M_V / N_V . d_V and θ_t is vertical element spacing and cell-specific electrical vertical tilting angle, respectively. By setting $\mathrm{G_k}$ to a diagonal matrix, we can avoid the scenario that more than one transceiver use same antenna elements at the same time. Each transceiver is connected to M_T/N_T antenna elements maintaining the aperture size of vertical dimension. Then, the effective antenna spacing for precoding can be a multiple of 0.5λ . As shown in Fig. 1, vertically λ and 2 λ spacing can be maintained with (4V, 2H) and (2V, 4H) 8Tx system, respectively.

3. Three-dimensional beamforming schemes

In this section, we derive two schemes to enable 3D beamforming with 2D transceiver under the conventional CSI feedback framework. First scheme (Scheme 1) is to use two separate CSI feedbacks instead of using single 8Tx CSI feedback. Each CSI report can be configured to measure different antenna sets in same eNB antennas. Note that the scheme 1 is to reconstruct the channel matrix by employing Kronecker product of two partial measurements (both vertical and horizontal). The second scheme (Scheme 2) is to exploit the conventional 8Tx codebook to supprt 2D antenna array. In this case, UE can directly use the conventional CSI feedback framework although 8Tx codebook does not perfectly fit to 2D antenna array. When compared to the legacy 8Tx system, 2D transceiver does not bring any additional computational complexity in the uplink reception.

(a) Scheme 1: One way is to configure two CSI processes for each dimension of antenna structure; one for horizontal CSI measurement and the other for vertical CSI measurement. Kronecker based codebook set can generates the combination of vertical and horizontal 1D PMI reports as

$$W^{(1),2D}_{m,n} = W^{(1),1D}_{m^v,n^v} \otimes W^{(1),1D}_{m^h,n^h},$$
$$W^{(2),2D}_{m,n} = W^{(1),1D}_{m^v,n^v} \otimes W^{(2),1D}_{m^h,n^h} \ or\ W^{(2),1D}_{m^v,n^v} \otimes W^{(1),1D}_{m^h,n^h} \quad (4)$$

(b) Scheme 2: Even though 2D 8Tx system has the same length of precoding weight, 8Tx codebook may not be feasible to 2D precoding weight. Nevertheless, reusing the conventional feedback framework, 8Tx codebook can be re-mapped to 2D transceiver of (4V, 2H) and (2V, 4H) system as

$$w_{m,n\ N_V\times N_H}^{(4V,2H)} = 1/\sqrt{8}[\ \underbrace{v_m}_{+45^\circ pol}\ \ \underbrace{\varphi_n v_m}_{-45^\circ pol}\ ]$$
$$w_{m,n\ N_V\times N_H}^{(2V,4H)} = \frac{1}{\sqrt{8}}\Big[\underbrace{\begin{matrix} e^{j4\pi m/32} & e^{j6\pi m/32} \\ 1 & e^{j2\pi m/32}\end{matrix}}_{+45^\circ pol}\ \underbrace{\begin{matrix}\varphi_n e^{j4\pi m/32} & \varphi_n e^{j6\pi m/32} \\ \varphi_n & \varphi e_n^{j2\pi m/32}\end{matrix}}_{-45^\circ pol}\Big] \quad (5)$$

4. Evaluation Results

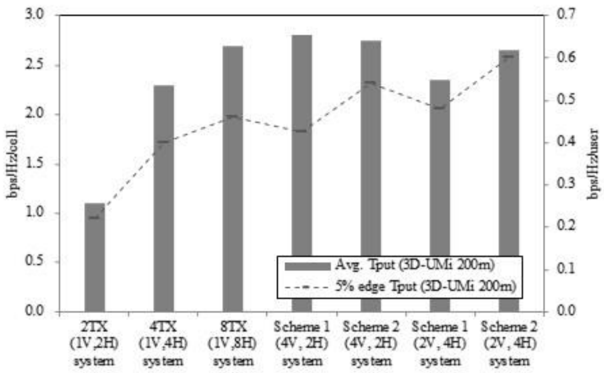

Fig. 2. Evaluation Results

In case of 3D-UMi deployment, both scheme 1 and 2 perform slightly better than 1D 8Tx system. This gain is mainly from the multi-user scheduling in vertical domain where eNB antenna is placed lower than UE location. As shown in the results, when the cell deployment size is smaller, more 3D beamforming gain can be achieved.