Binary Power Control for Sum Rate Maximization of Full Duplex Transmission in Multicell Networks

Ta-Hoang Vo*, Won-Joo Hwang*
*Dept of Information and Communication System, HSV-TRC, Inje University, Gimhae, 621-749, Korea
Email: tahoanght91@gmail.com, ichwang@inje.ac.kr

Abstract

The recent advances in wireless networks area have led to new techniques, such as small cells or full-duplex (FD) transmission, have also been developed to further increase the network capacity. Particularly, full-duplex communication promises expected throughput gain by doubling the spectrum compared to half-duplex (HD) communication. Because this technique permits one set of frequencies to simultaneously transmit and receive signals. In this paper, we focus on the binary power control for the users and the base stations in full-duplex multiple cellulars wireless networks to obtain optimal sum-rate under the effect interference and noise[1].

We investigate with a scenario in there one carrier is assigned to only one user in each cell and construct a model for this problem. In this work, we apply the binary power control by the its simplification in the implemented algorithm for both uplink and downlink simultaneously to maximize sum data rate of the system. At first, we realize the 2-cells case separately to check the optimal power allocation whether being binary. Then, we carry on with N-cells case in general through properties of binary power control.

Index Terms: Full-Duplex Communications, binary power control, sum-rate maximization.

I. INTRODUCTION

Most current wireless cellular networks are designed to operate uplink and downlink channels follow half-duplex mode. In time division duplex (TDD) systems, a node can transmit and receive signal at same frequency band, but at difference time slots, and in the frequency division duplex (FDD) systems, a node can transmit and receive signal simultaneously, but at different frequency band [1]. Thus, HD systems can not achieve the maximal spectral efficiency. Besides, FD radio, which can transmit and receive simultaneously on the same frequency band, has led to chance for increasing the spectral efficiency. Due to the potential of FD technology, number of researchers participated in the study about it, mostly on the physical layer. However, the FD systems exist the challenge of the strong self-interference at the front-end of receiver generated by the signal leakage from the transmitter antennas of a FD node to its own receiver antennas. In addition, the study of FD systems is more difficult because of the co-channel interference generated by the uplink users and the downlink users [4][5].

II. SYSTEM MODEL

We consider a full-duplex multi-cellular wireless networks that consist of the full-duplex nodes and each cell has only base station and one user as Figure 1.

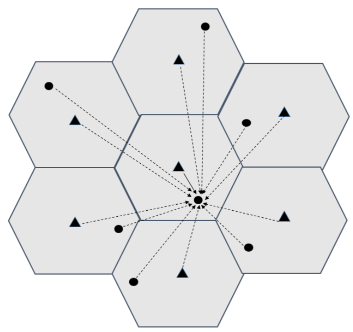

Figure 1: N-cell wireless system model in downlink phase, where N = 7. Base stations as solid triangles and users as solid circles. For the user in center cell, the desired communication link is shown as a solid line, whereas the interference link are shown as dashed lines.

Figure 1 represent N-cell wireless system model in downlink phase and for uplink phase we also represent in similar way. In our model, the wireless networks system has N cells and all nodes use a same frequency band, that is why leading in genaral to an interference and noise impaired system. The communication link are considered to be both downlink and uplink simultaneously. We denote p_n^u and p_n^d as the transmit power of user in uplink and BS in downlink of n^{th} cell, respectively, $G_{n,n}^u$ as the effective channel gain between BS and user in n^{th} cell, $G_{j,n}^u$ as the effective channel gain from user in j^{th} cell to BS in n^{th} cell, $G_{n,j}^d$ as the effective channel gain from BS in j^{th} cell to user in n^{th} cell. Each user and each BS are limited by maximum power value as: $P_{\min}^u \le p_n^u \le P_{\max}^u$, $P_{\min}^d \le p_n^d \le P_{\max}^d$, n = 1, 2, ... , N.

With uplink phase, we have the SINR of a pair base station (BS) and user in each cell as follow:

$$\mathrm{SINR}_n^{\,u} = \frac{p_n^u G_{n,n}^u}{\delta^2 + \sum_{\substack{j=1,\\ j\neq n}}^{N} p_j^u G_{j,n}^u + \sum_{\substack{j=1\\ j\neq n}}^{B} p_j^d G_{n,j}^d} \qquad (1)$$

Similarly, with downlink phase, the SINR of a pair BS and user in each cell is given by:

$$\mathrm{SINR}_n^{\,d} = \frac{p_n^d G_{n,n}^d}{\delta^2 + \sum_{\substack{j=1,\\ j\neq n}}^{N} p_j^d G_{n,j}^d + \sum_{\substack{j=1\\ j\neq n}}^{B} p_j^u G_{j,n}^u} \qquad (2)$$

where δ^2 is the variance of the independent zero-mean additive white Gaussian noise.

For the both downlink and uplink, the data rate of each pair BS and user in each cell is given by the Shannon formula, i.e, $R_n = \log_2(1+\mathrm{SINR}_n^u)+\log_2(1+\mathrm{SINR}_n^d)$

And for whole networks, we have the sum rate given by:

$$R = \sum_{n=1}^{N} (\log_2(1+\mathrm{SINR}_n^u)+\log_2(1+\mathrm{SINR}_n^d)) \qquad (3)$$

III. POWER CONTROL ALGORITHMS

This section presents the general optimal power allocation scheme $P^* = (P_1^{u*}, P_1^{d*}, \ldots, P_N^{u*}, P_N^{d*})$, which has as inputs the channel gain $\{G_{n,i}\}$. We need to solve the optimization problem follow as:

$$P^* = \arg\max_{P\in\Omega^N} R \qquad (4)$$

where

$\Omega^N = \{P \mid P_{\min}^u \le P_n^u \le P_{\max}^u, P_{\min}^d \le P_n^d \le P_{\max}^d, n = 1, \ldots, N\}$

is the feasible set and R is given in (3). Since Ω^N is a closed and bounded set and $R(P): \Omega^N \rightarrow R$ is continuous, (4) has a solution. We note that for $P_{\min}^u = 0$ and $P_{\min}^d = 0$. That mean some BS shut down the power completely [2][3].

A. The 2-cell Case

For the two-cell (N = 2), we can find a closed form solution by an analytical derivation. We consider that the uplink power and downlink power in each cell increase or decrease simultaneously. Therefore, we define $\Delta\Omega^2$ = { $(P_{1,\max}^u, P_{1,\max}^d, P_{2,\min}^u, P_{2,\min}^d)$, $(P_{1,\min}^u, P_{1,\min}^d, P_{2,\max}^u, P_{2,\max}^d)$, $(P_{1,\max}^u, P_{1,\max}^d, P_{2,\max}^u, P_{2,\max}^d)$}. The optimal power value is solution of below problem:

$$(P_1^{u*}, P_1^{d*}, P_2^{u*}, P_2^{d*}) = \arg\max_{(P_1^u, P_1^d, P_2^u, P_2^d)\in\Delta\Omega^2} R(P_1^u, P_1^d, P_2^u, P_2^d) \qquad (5)$$

The optimal power allocation is found among alternatives below:

- Extremal point on the boundaries of Ω^2 : I.e for $P_1^u = P_{1,\max}^u$, $P_1^d = P_{1,\max}^d$, then we search P_2^{u*} and P_2^{d*} through the partial derivative of R function.
- Corner points of Ω^2 is $\Delta\Omega^2$.

B. The N-cell Case (N > 2)

For N > 2, analytical derivation of the optimization problem is challenging and complexity. But we still consider to apply the properties of binary power allocation for this case because its simplification in design and implement. We define $\Delta\Omega^N$ is the set of corner points of Ω^N similar to 2-Cell Case. Hence, binary power control for N cells is solved by evaluating $R(P)$ at the set of corners points $\Delta\Omega^N$. We are trying to resolve this problem through binary power control in 3 cases mentioned in [3], 1) approximation by the arithmetic-geometric means inequality, 2) the low-SNIR regime and 3) the general case.

IV. CONCLUSIONS

In this paper, we only focus on binary power control for full duplex wireless networks sum rate maximization in 2-cell case. Besides, we deal with the power allocation problem and the solution for both 2-cell case and N-cell case (N>2). In addition, full-duplex is promissing, therefore, we try to study about binary power control for full duplex multicell wireless networks, that have led the challenges in solving the optimization problem.

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