

A Novel Bargaining Based Power Allocation for Coordinated Multiple Point Transmission/Reception

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Abstract— To explore the benefit of Coordinated Multiple Point transmission/reception (CoMP) will reduce the exchange overhead between the cells, a distributed Rubinstein-Stahl Bargaining based Power Allocation (DBPA) scheme is proposed in this paper. The introduced scheme can provide a possible solution to share the increased benefits, which are obtained at a serving cell when a slaving cell joins to coordinated transmission. By exchanging the Patience Factor (PF) calculated in each cell, a serving cell can determine the optimal power provided from the slaving cell. Furthermore, if the chosen slaving cell could get more utilities from cooperation, it will have incentive to do so. It is obvious that DBPA don't need a central control point then decrease the information transmission and the simulation results show that it can also achieve comparable performance to that employing centralized scheme.

Keywords— CoMP, power allocation, Rubinstein-Stahl Bargaining game, patience factor

I. INTRODUCTION

A significant requirement of LTE-Advanced system is to achieve the highly spectral efficiency for both cell-edge and cell-center users [1]. However, as the cell continues to grow smaller and the frequency reuse factor becomes nearly 1, inter-cell interference (ICI) becomes the major problem which limits the capacity in mobile networks. Recently, Coordinated Multiple Point transmission/reception (CoMP) is proposed for LTE-Advanced system [2], which is a promising inter-cell coordination technology to improve coverage and increase throughput especially in cell edge. As the better performance of throughput, joint processing (JP) technique is mainly be considered when CoMP is implemented. There two modes of JP, SU-MIMO mode, in which a single UE is served by two or more cells and MU-MIMO mode, in which multiple UEs are simultaneously served by two or more cells.

As CoMP should be introduced in the existing 3GPP LTE system, some information should be

exchanged through the X2 interface [3] when the cells cooperate with each other. As the limitation of the capacity of the X2 interface, the design of overhead is a challenge for the implementation of CoMP techniques, especially in the down-link.

In MU-MIMO JP mode, all the cooperated base stations must obtain the channel state information (CSI) of the multiple users, which may increase the information exchanging and the signal processing of LTE-A system. While in SU-MIMO JP mode, the situation can be better. So in this paper, we focus on SU-MIMO JP mode, and design distributed network architecture to implement CoMP, which use the Patience Factor (PF) as exchanging information to support slaving cell selection and coordinating transmission point decision and results in limited changes to the LTE Release 8.

The rest of this paper is organized as follows, in section II, the proposed architecture and the CoMP procedure is described; in section III, the details of proposed power allocation scheme are analysed; and in section IV, we give the numerical analysis results; and in the last section, we conclude our work.

II. ARCHITECTURE PROPOSAL FOR JP COMP

Our architecture proposal has minor changes from LTE Release 8 standard shown in figure 1 [1]. All the eNBs can be connected through X2 interface and all transmission points can receive the raw data from the serving gateway (S-GW) across the S1 interface as well. Furthermore, there is no central unit (CU) to control the eNBs, and all the decisions are made in the eNBs.

It is noted that coordination among all eNBs requires high backhaul capacity and is too complex

to implement. The authors in [4] propose cooperation should be constrained within a “cooperation set”. In actual transmission, only a part of CoMP cooperating set, which are named as “CoMP transmission points”, are active to join the coordination transmission. Therefore, a CoMP procedure can be divided into two steps, that are, in step 1, the base station judges that the user whether is a cell-center user or a cell-edge one through the SINR feedback. If a user is a cell-edge one, a “cooperation set” can be chosen by the user in a UE-specific [4] manner or decided by the base station; and in step 2, transmission points are chosen. In our scheme, the DBPA works for the CoMP transmission point selection and power allocation in SU-MIMO JP mode.

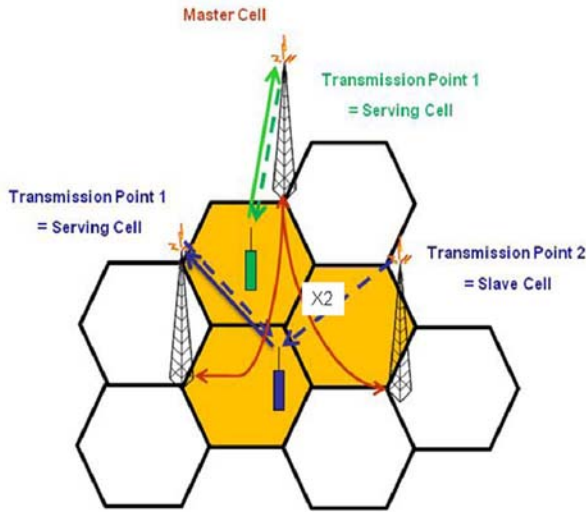


Figure 1. Network architecture

III. DBPA SCHEME

To reduce the information exchange, we propose a distributed bargaining based power allocation (DBPA) scheme to enable the base stations to make decision of the transmission points and the cooperating power. The details go as follows.

A. Utility Model

We got the concept of utility from economics, which can be used to depict the QoS satisfaction degree (QSD) of the network service. Different bit rate of the service corresponds to a different QSD of the user, which can be got by the utility function. A utility function is a concave function and the

choice of it depends on the upper layer application, such as VoIP, IPTV, FTP and so on. In this paper, we choose the utility function [5] below to describe the relationship between the bit rate and the QSD.

$$U(R) = \begin{cases} a(1 - e^{-bR}) & \text{if } R \geq 0 \\ 0 & \text{if } R < 0 \end{cases} \quad (1)$$

where a and b are strictly positive real numbers. a is the upper limit of the utility and b determines the curve's shape. R is the achieve rate calculated from two types:

1) The data transformed by single cell:

$$R_{k,i}^m = B \log_2 \left(1 + \alpha \frac{P_{k,i}^m G_{k,i}^m}{\sigma^2 + \sum_{n=1, n \neq k, l}^{N_{cell}} P_{n,i}^m G_{n,i}^m} \right) \quad (2)$$

2) The data transformed under CoMP mode:

$$R_{k,i}^m = B \log_2 \left(1 + \alpha \frac{P_{k,i}^m G_{k,i}^m + P_{l,k,i}^{comp} G_{l,i}^m}{\sigma^2 + \sum_{n=1, n \neq k, l}^{N_{cell}} P_{n,i}^m G_{n,i}^m} \right) \quad (3)$$

where α is a constant capacity gap specified as $\alpha = -\frac{1.5}{\ln(5P_{BER})}$ [6], P_{BER} is the target BER. $P_{k,i}^m$ is the power allocated to UE_i by BS_k on RB_m (the m th Radio Bear), and $P_{l,k,i}^{comp}$ is the cooperating power from BS_l to UE_i . $G_{k,i}^m$ is the channel gain on RB_m from BS_k to UE_i . For simplification, it is assumed that the transmitter and receiver are equipped with single antenna and applying Alamouti code scheme in CoMP mode.

While applying CoMP to the users, the utility of the slaving cell will decrease just because part of its power offered to other cells, as well as the utility of the master cell will increase just because it is offered additional power by other cells. We can describe the utility decrease of the slaving cell and increase in the serving cell as follows.

1) Slaving Cell Utility Decrease

We assume slaving cell BS_l provides power $P_{l,k,i}^{comp}$ to help the cell-edge user UE_i in serving cell BS_k . Thus, the total power $P_l^{left} - P_{l,k,i}^{comp}$ in slaving cell BS_l needs reallocated and the utility reduce of each UE can be defined as:

$$\Delta U_{l,j}(P_{l,j}^{n,new}) = U(R_{l,j}(P_{l,j}^n)) - U(R_{l,j}(P_{l,j}^{n,new})) \quad (4)$$

And the total utility decrease in the slaving cell l is:

$$\Delta U_l(P_{l,k,i}^{comp}) = \sum_{j=1}^N \Delta U_{l,j} \quad (5)$$

Where N is the amount of users within slaving cell l .

2) Serving Cell Utility Increase:

As the cell-edge user i has been already jointly transmitted by the serving and slaving cell. The serving cell k could save some power in the cell-edge user i and benefit all the users through water-filling algorithm. Therefore, each user's utility increases by

$$\Delta U_{k,i}(P_{k,i}^{m,new}) = U(R_{k,i}(P_{k,i}^{m,new})) - U(R_{k,i}(P_{k,i}^m)) \quad (6)$$

And the total increase in serving cell k is

$$\Delta U_k(P_{l,k,i}^{comp}) = \sum_{i=1}^N \Delta U_{k,i} \quad (7)$$

B. Rubinstein-Stahl bargaining in DBPA Scheme

Rubinstein-Stahl is applied in this paper as tool to realize the distributed bargaining model which describes both sides of cooperating cells how to share the serving cell utility increase through bargaining. The bargaining procedure is as follows. In round 0, the serving cell begins by providing an offer, say $(x, 1-x)$, where $0 \leq x \leq 1$ represents the part of the utility that it wants for itself. If the slaving accepts, the agreement is reached; otherwise, a period of bargaining time $\Delta > 0$ elapses. Then comes to round 1, the roles turn to the slaving cell and make a new offer $(y, 1-y)$, where $0 \leq y \leq 1$ is the fraction of the utility which the slaving is interested in. The serving must either accept the new offer, or reject it, in which time Δ must elapse before the slaving makes a new offer.

Obviously, both sides have their patience during the bargaining. A more patient cell benefits more from the negotiations. Due to the impatience of both the players, there will be a final agreement act.

C. Patience Factor

In this distributed bargaining model, the patience factor is the key factor that affects the negotiation process of both sides. We will present how to determine the patience factor in the serving and the slaving respectively.

1) The Patience Factor of Serving Cell:

As has been stated before, cooperating will result in serving cell utility increase, but the marginal utility with $P_{l,k,i}^{comp}$ may decrease. It is obvious that the more marginal utility the serving attains the less patience it has in bargaining. Moreover, the patience factor is from zero to one. As a result, we can define the conditions for patience functions of the serving as follows

$$\frac{d\delta_{serving}(t)}{dt} < 0, \delta_{serving}(0) = 1, \delta_{serving}(\infty) = 0 \quad (8)$$

Where $t = \frac{d(\Delta U_l(P_{l,k,i}^{comp}))}{dP_k}$ is the marginal utility increase of serving cell k if the slaving cell l provides power $P_{l,k,i}^{comp}$ to help.

Any functions satisfying the above conditions could be used to express the patience function of the serving. In this paper, we adopt the following function for the patience of serving [7].

$$\delta_{serving}(t) = 1 - \frac{e^{\mu t} - e^{-\mu t}}{e^{\mu t} + e^{-\mu t}} \quad (9)$$

Where μ is a serving cell patience coefficient.

2) The Patience Factor of Slaving Cell:

In contrast to serving cell, the utility loss of the slaving in (5) is a monotonous increasing function of the power $P_{l,k,i}^{comp}$ and the marginal utility loss is increasing, too. Therefore, the more the marginal utility the slaving loses, the more patience it will have. Thus the conditions of patience function of the slaving are

$$\frac{d\delta_{slaving}(t)}{dt} > 0, \delta_{slaving}(0) = 0, \delta_{slaving}(\infty) = 1 \quad (10)$$

And the function adopted is,

$$\delta_{slaving}(t) = \frac{e^{\lambda t} - e^{-\lambda t}}{e^{\lambda t} + e^{-\lambda t}} \quad (11)$$

Where λ is a slaving cell patience coefficient.

D. Share the Utility Increase

In this model, there exists a unique Nash Equilibrium for the bargaining game [8]. After several rounds of bargaining, both sides will finally come to an agreement. According to the Nash Equilibrium, the final agreement will be as follows.

$$(Share_{serving}, Share_{slaving}) = \left(\frac{1 - \delta_{slaving}}{1 - \delta_{serving} \delta_{slaving}}, \frac{\delta_{slaving} (1 - \delta_{serving})}{1 - \delta_{serving} \delta_{slaving}} \right) \quad (12)$$

As the serving cell taking the first action, the decision will be made by the serving side to maximizing its utility with the following objective function.

$$\max_{P_{l,k,i}^{comp}} \Delta U_k(P_{l,k,i}^{comp}) Share_{serving}(P_{l,k,i}^{comp}) \quad (13)$$

At last, the slaving cell will check whether the utility it obtains is greater than its loss in (5) and send the judgment back to the serving cell.

Our DBPA model is a complete information bargaining game, these final results of the game should be calculated in both sides only by the exchanged patience factors, but neither needs the real bargaining between them nor utility of each user fed back to the central controller so as to decrease the signalling added and the time cost.

E. CoMP with DBPA Scheme Implementation

1) When a serving cell k initiates a service to user i , it has to judge the user type (whether it is a cell-edge user) according to the channel state fed back and send CoMP request (if it is a cell-edge one) to the slaving cell l chosen from the RSRP list.

2) After receiving the request, the slaving cell l should calculate the transmission utility by (4) and (5) and then quantize them to the patience through (11). The result will be sent back to the serving cell k .

3) The serving cell k will calculate its patience in the same way by (6), (7) and (9). Based on the consideration of both sides patience, it will calculate the share proportion by (12) and work out the optimal answer to (13). Slaving cell l will be informed of its share.

4) At last, the slaving cell should evaluate if the utility increase by CoMP can compensate the utility loss by share its power to others. If so, the CoMP agreement is reached, and the slaving cell becomes one of CoMP transmission points. Otherwise, it fails.

5) All the CoMP transmission points transmit the data to the cell-edge user at the same time in SU-MIMO mode.

IV. NUMERICAL ANALYSIS

Consider the scenario with 7 eNBs wrap-around network topology and the distance between the eNBs is 500 meters. The value of main simulation parameter assigned as $f_c = 2$ GHz, $B = 5$ MHz, $N_o = -174$ dBm/Hz, The receiver figure is 9dB and the max transmit power at each cell is assigned as 43dBmW. Moreover, the SINR threshold used to determine the user type is 0dB and $a = 100$, $b = 0.03$ in (1), $\mu = 50$ in (9), $\lambda = 10$ in (11) when calculating the utility and patience factor, respectively. When the number of cell-edge users per cell varies from 1 to 3, we investigate the CDF of utility increase in two cases: 1) The Proposed DBPA Scheme; 2) Central Control (CC) Scheme. The results of utility increase come as Figure 2.

Central Control Scheme is an ideal scheme and aim at maximizing the total utility increase within the CoMP transmission points.

$$\max_{P_{l,k,i}^{comp}} \Delta U_k(P_{l,k,i}^{comp}) - \Delta U_l(P_{l,k,i}^{comp}) \quad (14)$$

Obviously, it need a Central Unit (CU) to control all the eNBs, and all the channel state information should be transferred between CU and eNBs.

From the figure 2, it can be seen that,

1. In the two schemes, the utility of the system is dramatically improved and the larger the cell-edge user number, the better performance is achieved.
2. DBPA and CC scheme has almost the similar performance when the cell-edge user number is 1.
3. DBPA has a little worse performance on utility improvement than CC scheme when the number of the cell edge users is 2 or 3. But in DBPA scheme, only patience factor exchanging is needed.

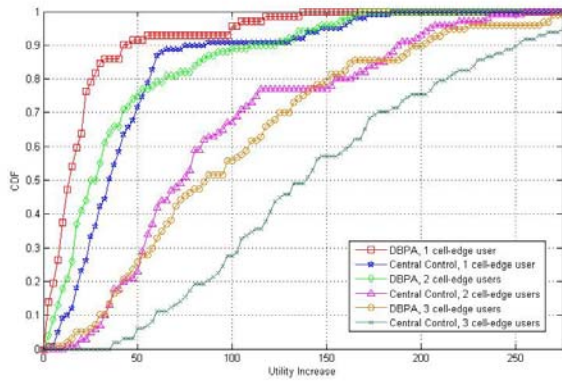


Figure 2. Utility increase geometry in different cases

V. CONCLUSIONS

In this letter, we propose a Rubinstein-Stahl Bargaining based power allocation (DBPA) scheme for CoMP. By sharing the benefits of CoMP, no central unit is need. This scheme dramatically reduces the exchange between cells and so as to release the burden of X2 interface. Simulation results show the effectiveness of it.

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