Multicell power allocation method based on game theory for inter-cell interference coordination

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As a new technology, coordinated multipoint (CoMP) transmission is included in LTE-Advanced study item. Moreover, the network architecture in LTE-Advanced system is modified to take into account co-ordinated transmission. Under this background, a novel power allocation game model is established to mitigate inter-cell interference with cellular coordination. In the light of cellular cooperation relationship and centralized control in eNodeB, the power allocation in each served antenna unit aims to make signal to interference plus noise ratio (SINR) balanced among inter-cells. Through the proposed power allocation game algorithm, the users' SINR can reach the Nash equilibrium, making it feasible to reduce the co-frequency interference by decreasing the transmitted power. Numerical results show that the proposed power allocation algorithm improves the throughput both in cell-center and cell-edge. Moreover, the blocking rate in cell-edge is reduced too.

LTE-Advanced, inter-cell interference coordination, CoMP, game theory, power allocation

1 Introduction

In May 2008, coordinated multipoint (CoMP) transmission is included in the 3GPP working meetings, and listed as one study item in LTE-Advanced[1]. CoMP schemes are seen by many companies as one of the main techniques to improve the system capacity and the coverage of LTE-Advanced systems[2].

According to ref. [3], there are two scenarios in CoMP transmission. One scenario is only carried out between antenna ports within one cell, implying that the current LTE multi-antenna-port structure needs to support for up to four different cell-specific reference signals. The other scenario is carried out between antenna ports corresponding to different cells. In the general case of the CoMP approach of Figure 1, several antenna units (AUs) are connected to a central eNodeB, and the users can be served by different AUs and even by

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more than one eNodeB cooperatively.

In orthogonal frequency division multiplexing (OFDM) systems, the sub-carriers are orthogonal in intra-cell and the intra-cell interference can be effectively avoided, but as the co-frequency sub-carriers are reused among multiple cells, extra inter-cell interference may be induced. In 3GPP LTE proposals, inter-cell interference coordination is accepted as an important method in mitigating inter-cell interference[4].

However, some methods are still not specific. Among these proposals, the power allocation strategy is given, which takes the partial power in cell-center and the full power in cell-edge[5,6], written as the fixed power allocation (FPA). This method enables to suppress the co-frequency interference from cell-center, but the performance for cell-center users may degrade and the interference from cell-edge users may increase. Furthermore, this power allocation scheme faces a challenge with the emergence of coordinated transmission in CoMP, for the architecture of network has been modified. In this scenario, the inter-cell interference may become an important problem.

By means of cellular coordination, a novel multicell non-cooperative power allocation game (NPAG), based on the principle of inter-cell balanced SINR, is proposed to mitigate the inter-cell interference. By means of game theory, the threshold SINR are set as the objective function and the optimum power allocation strategy is obtained when the inter-cell SINR reaches the Nash equilibrium. With this power allocation strategy, the inter-cell interference can be reduced significantly.

The rest of this paper is organized as follows: The system model is introduced in section 2. The power allocation based on game theory is proposed in section 3. The performance analysis is given in section 4. Finally, some conclusions are drawn in section 5.

2 System model

As shown in Figure 1, the topology of cellular coordination is given, where each AU covers a single cell, and three AUs are centrally connected into one eNodeB[7]. By the enhanced X2 interface, eNodeB are connected with each other. In cell-edge region, users can be served by one or several AUs that are controlled respectively by the same eNodeB or different eNodeBs. Moreover, each AU can be exchanged with each other from the same eNodeB, or other different eNodeBs.

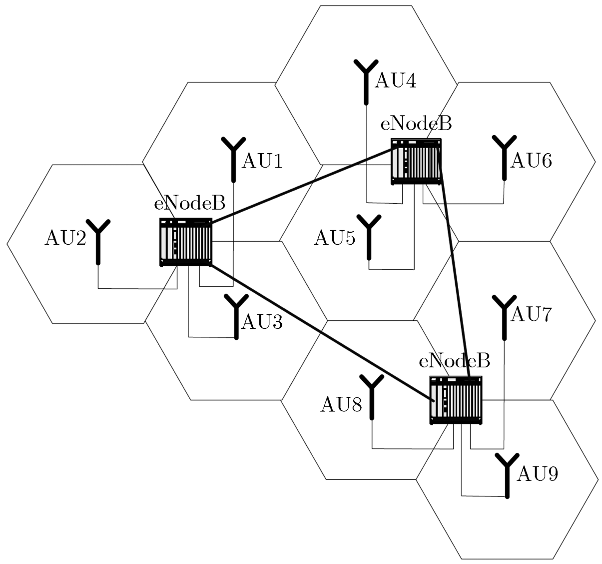

Figure 1 Topology of cellular coordination.

Under this cellular coordination architecture, the users with co-frequency subcarriers can exchange SINR information from AUs and eNodeBs. By means of such an exchange and centralized control, we consider optimizing power allocation, in order to effectively mitigate inter-cell interference.

Consider the downlink of a multi-cell system with n co-channel cells, where M subcarriers are reused in the system. Each cell consists of mobile users and their assigned AU. Since the same frequency bands are reused by multiple cells, users assigned with the same frequency may be interfered with each other. Therefore, the SINR of the user k, which is placed in the cell i, with the subcarrier m taken into consideration, is expressed as[8]

$$\gamma_{i,k,m} = \frac{g_{i,k,m} p_{i,m}}{\sum_{j=1,j\neq i}^{n} g_{j,k,m} p_{j,m} + N_0}, \tag{1}$$

where $\gamma_{i,k,m}$ is the k^{th} user's SINR at the subcarrier m $(m = 1, 2, \ldots, M)$; $g_{i,k,m}$ denotes the downlink channel gain of the subcarrier m from cell i to user k; $p_{i,m}$ stands for the downlink power of the subcarrier m from cell i; N_0 is the noise of the channel m in user k. From the above expression, we can denote the interference plus noise by I_i, that is,

$$I_i = \sum_{j=1,j\neq i}^{n} g_{j,k,m} p_{j,m} + N_0. \tag{2}$$

To simplify the calculation, we take the user k and the subcarrier m as an example, and write $\gamma_{i,k,m}$ as γ_i, $g_{i,k,m}$ as g_i, and $p_{i,m}$ as p_i. Therefore, eq. (1) and eq. (2) can be rewritten as

$$\gamma_i = \frac{g_i p_i}{I_i}, \tag{3}$$

$$I_i = \sum_{j=1,j\neq i}^{n} g_j p_j + N_0. \tag{4}$$

In order to mitigate the inter-cell interference, we consider establishing balanced SINR by cellular coordination. On this basis, the co-frequency power in AU is allocated. Considering the types of services, the different threshold SINR can be set for users in cell, and the objective function is given as follows:

$$\begin{aligned} &\min \sum_{i=1}^{n} c_i |\gamma_i - \gamma_i^{th}| \\ &\text{s.t.} \begin{cases} 0 \leqslant p_i \leqslant p_i^{\max}, \\ \sum_{i=1}^{n} c_i = 1, \end{cases} \end{aligned} \tag{5}$$

where c_i is a relaxation factor, and the allocated power p_i is subjected to the maximum power $p_i^{\max}$. Based on the objective function, we establish a power allocation game model to solve the optimum value.

3 Power allocation based on game theory

Assume that $G = \{\Omega, \{p\}, u(\cdot)\}$ is the multicell non-cooperative game model[9]. In such a model, Ω is the set of participants, $\Omega = \{1, 2, \ldots, M\}$, which is constructed by the cells with co-frequency subcarriers. $\{p\}$ is the power strategy space, where $\{p\} = \{p | 0 \leqslant p \leqslant p^{\max}\}$. $u(\cdot)$ is the utility function of this game model[10].

In the downlink, the optimum power strategy is allocated to each AU by the centralized eNodeBs, which make the utility function reach the Nash equilibrium. Based on the objective function in eq. (5), we give the utility function as follows:

$$u(p_i) = a_i \sqrt{|\gamma_i - \gamma_i^{th}|} - b_i p_i. \tag{6}$$

In eq. (6), $a_i \sqrt{|\gamma_i - \gamma_i^{th}|}$ is the cost function, and $b_i p_i$ is the punishment factor. On this basis, the optimum power based on the no-cooperative power game model is analyzed. Moreover, the existence and uniqueness of Nash equilibrium are proved.

3.1 Nocooperative game model

Simplifying eq. (6), we can get

$$u(p_i) = \begin{cases} a_i \sqrt{\gamma_i - \gamma_i^{th}} - b_i p_i, \gamma_i \geqslant \gamma_i^{th}, \\ a_i \sqrt{\gamma_i^{th} - \gamma_i} - b_i p_i, \gamma_i < \gamma_i^{th}. \end{cases} \tag{7}$$

When $\gamma_i \geqslant \gamma_i^{th}$, $u(p_i) = a_i \sqrt{\gamma_i - \gamma_i^{th}} - b_i p_i$.

Considering $\gamma_i = \frac{g_i p_i}{I_i}$, eq. (7) can be rewritten as

$$\frac{\partial u(p_i)}{\partial p_i} = \frac{1}{2} a_i (\gamma_i - \gamma_i^{th})^{-\frac{1}{2}} \frac{g_i}{I_i} - b_i. \tag{8}$$

Let $\frac{\partial u(p_i)}{\partial p_i} = 0$. Then we have $\gamma_i = \gamma_i^{th} + (\frac{a_i g_i}{2 b_i I_i})^2$. Combined with $\gamma_i = \frac{g_i p_i}{I_i}$, eq. (8) becomes

$$f(p_i) = \frac{I_i}{g_i} \gamma_i^{th} + \left(\frac{a_i}{2b_i}\right)^2 \frac{g_i}{I_i}. \tag{9}$$

Combining the above expression with $I_i = \sum_{j=1,j\neq i}^{n} g_j p_j + N_0$, and applying the Newton iterations, the iterative power allocation can be expressed as

$$p_i^{(n)} = \frac{p_i^{(n-1)}}{\gamma_i^{(n-1)}} \gamma_i^{th} + \left(\frac{a_i}{2b_i}\right)^2 \frac{\gamma_i^{(n-1)}}{p_i^{(n-1)}}. \tag{10}$$

When $\gamma_i < \gamma_i^{th}$, $u(p_i) = a_i \sqrt{\gamma_i^{th} - \gamma_i} - b_i p_i$.

Similarly, let $\frac{\partial u(p_i)}{\partial p_i} = 0$. Using the Newton iterations, we have

$$s(p_i) = \frac{I_i}{g_i} \gamma_i^{th} - \left(\frac{a_i}{2b_i}\right)^2 \frac{g_i}{I_i}, \tag{11}$$

$$p_i^{(n)} = \frac{p_i^{(n-1)}}{\gamma_i^{(n-1)}} \gamma_i^{th} - \left(\frac{a_i}{2b_i}\right)^2 \frac{\gamma_i^{(n-1)}}{p_i^{(n-1)}}. \tag{12}$$

Returning to the objective function (5), we need to add a power constraint in our power allocation since the iterative power is limited by the maximum value. Therefore, the optimum power allocation equation is finally given by

$$p_i^{(n)} = \begin{cases} p_i^{\max}, p_i^{(n)} \geqslant p_i^{\max}, \\ \dfrac{p_i^{(n-1)}}{\gamma_i^{(n-1)}}\gamma_i^{th} + \left(\dfrac{a_i}{2b_i}\right)^2 \dfrac{\gamma_i^{(n-1)}}{p_i^{(n-1)}}, \\ \qquad \gamma_i \geqslant \gamma_i^{th}, p_i^{(n)} < p_i^{\max}, \\ \dfrac{p_i^{(n-1)}}{\gamma_i^{(n-1)}}\gamma_i^{th} - \left(\dfrac{a_i}{2b_i}\right)^2 \dfrac{\gamma_i^{(n-1)}}{p_i^{(n-1)}}, \\ \qquad \gamma_i < \gamma_i^{th}, p_i^{(n)} < p_i^{\max}. \end{cases} \tag{13}$$

3.2 Existence of Nash equilibrium

According to the principles in game theory[9], if the Nash equilibrium exists in $G = \{\Omega, \{p\}, u(\cdot)\}$, it should meet the following conditions:

1) $\{p\}$ is a convex set in Euclidean space, which is non-empty, closed, and bounded;

2) $u(\cdot)$ is not only continuous in the strategy space, but also is a convex function or concave function.

Assuming that the power allocation is non-negative and constrained by the maximum value, the power in the strategy must be in a close range $[0, p^{\max}]$. Naturally, it is non-empty, closed, and bounded. On the other hand, when $\gamma_i \geqslant \gamma_i^{th}$ and $\gamma_i < \gamma_i^{th}$, $u(p_i)$ is continuous. Specially, when $\gamma_i = \gamma_i^{th}$, we have

$$\lim_{\gamma_i \to \gamma_i^{th}-0} u(p_i) = \lim_{\gamma_i \to \gamma_i^{th}+0} u(p_i). \tag{14}$$

From the above equation, we know that the left limit is equal to the right limit. So $u(p_i)$ is also continuous inγ_i^{th}. By this analysis, $u(p_i)$ is continuous in the strategy space.

In order to prove $u(p_i)$ to be a convex function, we need to calculate its second-order partial derivative.

$$\frac{\partial^2 u(p_i)}{\partial p_i^2} = \begin{cases} \dfrac{1}{2} a_i (\gamma_i - \gamma_i^{th})^{-\frac{3}{2}} \left(\dfrac{g_i}{I_i}\right)^2, \\ \qquad \gamma_i \geqslant \gamma_i^{th}, \\ \dfrac{1}{2} a_i (\gamma_i^{th} - \gamma_i)^{-\frac{3}{2}} \left(\dfrac{g_i}{I_i}\right)^2, \\ \qquad \gamma_i < \gamma_i^{th}. \end{cases} \tag{15}$$

By eq. (15), it is straightforward that $\frac{\partial^2 u(p_i)}{\partial p_i^2} \geqslant 0$, which proves the convexity of the function $u(p_i)$.

In a word, the proposed game model meets principle 1) and principle 2), so we have proved that such a model exists with the Nash equilibrium.

3.3 Uniqueness of Nash equilibrium

By the principle of game theory, the iterative expression for the power allocation converges to one point when the following conditions are given:

- Positivity: If $p > 0$, then $f(p) > 0$, $s(p) > 0$.
- Monotonicity: If $p' > p$, then $f(p') > f(p)$, $s(p') > s(p)$.
- Scalability: For $\forall \alpha > 1$ and $p > 0$, then $\alpha f(p) > f(\alpha p)$, $\alpha s(p) > s(\alpha p)$.

The proof is as follows:

(I) Positivity. When $p > 0$,

$$f(p) = \frac{I_i}{g_i}\gamma_i^{th} + \left(\frac{a_i}{2b_i}\right)^2 \frac{g_i}{I_i} > 0, \tag{16}$$

$$s(p) = \frac{1}{g_i I_i}\left(I_i\sqrt{\gamma_i^{th}} - \frac{a_i g_i}{2b_i}\right) \cdot \left(I_i\sqrt{\gamma_i^{th}} + \frac{a_i g_i}{2b_i}\right). \tag{17}$$

Assuming that $I_i > \frac{a_i g_i}{2b_i\sqrt{\gamma_i^{th}}}$, from eqs. (16) and (17) it follows that $f(p) > 0$, $s(p) > 0$.

(II) Monotonicity.

$$f(p') - f(p) = (I_{i(p')} - I_{i(p)}) \cdot \left[\frac{\gamma_i^{th}}{g_i} - \left(\frac{a_i}{2b_i}\right)^2 \left(\frac{g_i}{I_{i(p')} \cdot I_{i(p)}}\right)\right], \tag{18}$$

$$s(p') - s(p) = (I_{i(p')} - I_{i(p)}) \cdot \left[\frac{\gamma_i^{th}}{g_i} + \left(\frac{a_i}{2b_i}\right)^2 \left(\frac{g_i}{I_{i(p')} \cdot I_{i(p)}}\right)\right]. \tag{19}$$

If $p' > p$, then $I_{i(p')} > I_{i(p)}$. Moreover, assuming that $I_{i(p)} > \frac{a_i g_i}{2b_i\sqrt{\gamma_i^{th}}}$, we can obtain $f(p') - f(p) > 0$, $s(p') - s(p) > 0$.

(III) Scalability. $\forall \alpha > 1$, we have

$$\begin{aligned} \alpha f(p) - f(\alpha p) &= \frac{\gamma_i^{th}}{g_i}(\alpha I_{i(p)} - I_{i(\alpha p)}) \\ &\quad + \left(\frac{a_i}{2b_i}\right)^2 \left(\frac{\alpha g_i}{I_{i(p)}} - \frac{g_i}{I_{i(\alpha p)}}\right), \end{aligned} \tag{20}$$

$$\alpha s(p) - s(\alpha p) = \frac{\gamma_i^{th}}{g_i}(\alpha I_{i(p)} - I_{i(\alpha p)})$$

$$-\left(\frac{a_i}{2b_i}\right)^2\left(\frac{\alpha g_i}{I_{i(p)}}-\frac{g_i}{I_{i(\alpha p)}}\right). \tag{21}$$

Combined with $I_i=\sum_{j=1,j\neq i}^{n} g_j p_j+N_0$, the algebra factor $\alpha I_{i(p)}-I_{i(\alpha p)}$ in eqs. (20) and (21) can be derived as $\alpha I_{i(p)}-I_{i(\alpha p)}=(\alpha-1)N_0>0$. Moreover, for $\frac{\alpha g_i}{\sum_{j=1,j\neq i}^{n} g_j p_j+N_0}>\frac{g_i}{\sum_{j=1,j\neq i}^{n}\alpha g_j p_j+N_0}$, we can get $\frac{\alpha g_i}{I_{i(p)}}-\frac{g_i}{I_{i(\alpha p)}}>0$. So we have $\alpha f(p)-f(\alpha p)>0$.

On the other hand, in order to prove $\alpha s(p)-s(\alpha p)>0$, we introduce the following inequality:

$$\frac{(\alpha^2-1)g_i}{\alpha I_{i(p)}}=\frac{\alpha g_i}{I_{i(p)}}-\frac{g_i}{\alpha I_{i(p)}}>\frac{\alpha g_i}{I_{i(p)}}-\frac{g_i}{I_{i(\alpha p)}}. \tag{22}$$

So,

$$\alpha s(p)-s(\alpha p)>\frac{\gamma_i^{th}}{g_i}\cdot(\alpha-1)N_0-\left(\frac{a_i}{2b_i}\right)^2\cdot\frac{(\alpha^2-1)g_i}{\alpha I_{i(p)}}.$$

Again, assuming that

$$I_{i(p)}>\left(\frac{a_i}{2b_i}\right)^2\cdot\frac{(\alpha+1)g_i^2}{\alpha N_0\gamma_i^{th}},$$

we have $\alpha s(p)-s(\alpha p)>0$.

From the above proof process, we can conclude that $f(p)$ and $g(p)$ can meet all the requirements if

$$I_{i(p)}>\mathrm{Max}\left[\left(\frac{a_i}{2b_i}\right)^2\cdot\frac{(\alpha+1)g_i^2}{\alpha N_0\gamma_i^{th}},\frac{a_i g_i}{2b_i\sqrt{\gamma_i^{th}}}\right]. \tag{23}$$

Therefore, the proposed power allocation algorithm converges to a single point.

3.4 NPAG algorithm

Take the user k and the subcarrier m as an example. The steps of this power allocation algorithm are given as follows:

Step 1. Set the initial parameters, such as the initial power $p_i^{(0)}$, the noise power v_i, and the threshold SINR γ_i^{th}. Specially, take the partial power in cell-center and the full power in cell-edge.

Step 2. According to the following power allocation equation, update the power $p_i^{(n)}$ in the next iteration ($n\geqslant 1$):

$$p_i^{(n)}=\begin{cases} p_i^{\max}, p_i^{(n)}\geqslant p_i^{\max}, \\ \frac{p_i^{(n-1)}}{\gamma_i^{(n-1)}}\gamma_i^{th}+\left(\frac{a_i}{2b_i}\right)^2\frac{\gamma_i^{(n-1)}}{p_i^{(n-1)}}, \\ \qquad \gamma_i\geqslant\gamma_i^{th}, p_i^{(n)}<p_i^{\max}, \\ \frac{p_i^{(n-1)}}{\gamma_i^{(n-1)}}\gamma_i^{th}-\left(\frac{a_i}{2b_i}\right)^2\frac{\gamma_i^{(n-1)}}{p_i^{(n-1)}}, \\ \qquad \gamma_i<\gamma_i^{th}, p_i^{(n)}<p_i^{\max}. \end{cases} \tag{24}$$

Step 3. Compute $\gamma_i^{(n)}$ when the power is $p_i^{(n)}$.

Step 4. If $|\gamma_i^{(n)}-\gamma_i^{th}|\leqslant\varepsilon$, output $p_i^{(n)}$ and stop. Else, go to the next step.

Step 5. If $p_i^{(n)}\leqslant p_i^{\max}$, $n=n+1$, then go back to step 2. Else, remove the user with the minimum SINR, reset the priorities and go back to step 1.

For power iteration in the above steps, the complexity of NPAG algorithm is $O(n^2)$. Since the FPA algorithm needs no iteration, its complexity is $O(1)$, less than NPAG algorithm.

Throughout the text, we have proposed an NPAG algorithm based on inter-cell balanced SINR, and proved the existence and uniqueness of the Nash equilibrium. In the next section, the NPAG algorithm is simulated in a multi-cell scenario. Also, its performance is compared to that of the FPA algorithm.

4 Performance analysis

By means of Matlab software, the Monte Carlo method is taken in simulation. We consider 9 cells, with a cell radius of 1 km. The users are uniformly distributed in the cell area and the wraparound technique is invoked. Besides, the frequency reuse scheme follows soft frequency reuse (SFR) approach[11]. The center carrier frequency is assumed to be 2 GHz, the inter-site distance (ISD) is 866 m, and the cell-center users and the cell-edge users are distinguished by such an ISD. Furthermore, the system bandwidth is set at 1.25 MHz with the bandwidth of each subcarrier equal to 15 kHz and the overall transmit power per cell equal to 43 dBm[12].

In the downlink, the multipath fading model is set as the tapped delay-line spatial channel model extended (SCME)[13]. Both the number of cell antenna unit and the number of user equipment antenna are set at 1. Moreover, the pathloss model is modeled as[14]

$$PL(d) = 128.1 + 37.6 \lg d[\text{dB}]. \quad (25)$$

Furthermore, we compare the throughputs and blocking rate with the change of the frequency reuse factor (FRF) in cell, for the NPAG and FPA algorithms. Specifically, the throughputs can be calculated according to Shannon's theory: the throughputs of all cell-center users are added up and written as the throughputs in cell-center. Similarly, the throughputs of all cell-edge users are added up and written as the throughputs in cell-edge. On the other hand, if one user's SINR is below a specified SINR value, it is blocked in simulation. We count up the ratio of the blocked users and the whole users, and write them as the blocking rate.

The throughputs in cell-center are compared in Figure 2. As the FRF increases, more subcarriers are allocated to the cell-center, and hence, the throughput is also increased. Given a certain FRF, the NPAG algorithm outperforms the throughput achieved by the FPA algorithm. This can be explained as follows.

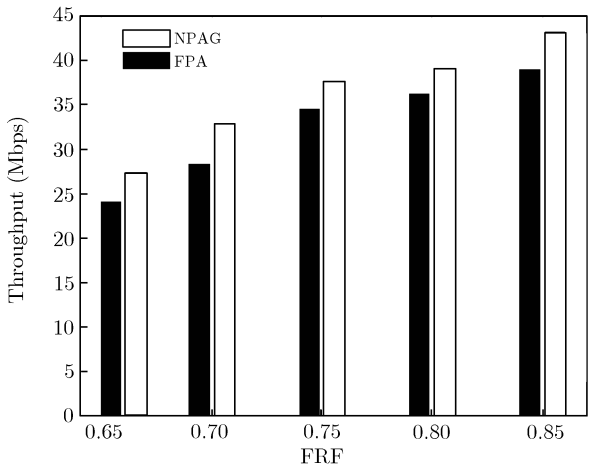

Figure 2 Throughput comparison in cell-center.

The FPA algorithm allocates partial power to users in cell-center. This power allocation scheme limits the interference experienced by the users but it also limits the achievable throughput, since users with good channel conditions receive a limited amount of power. However, in the case of the NPAG algorithm, the Nash equilibrium is established for the power allocation, which aims to keep a balanced inter-cell SINR. Therefore, users in the cell-center with good channel conditions benefit from the redundant power in the cell-edge.

Figure 3 shows the throughput comparison in cell-edge. In this case, the throughput decreases as the FRF increases, since fewer subcarriers are allocated to the users in the cell-edge. However, given a certain FRF, the NPAG outperforms again the throughput achieved by the FPA algorithm. This can be explained as follows.

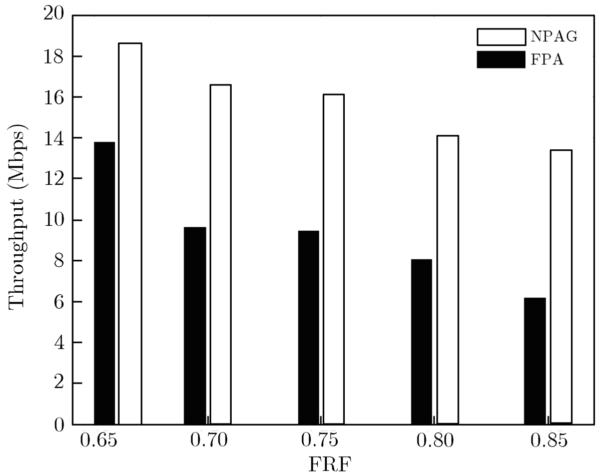

Figure 3 Throughput comparison in cell-edge.

The FPA algorithm allocates full power to users in cell-edge. This fact allows to compensate for the pathloss related to poor channel conditions, but the redundant power may bring about interference to the other co-frequency users, especially when users are served by multiple AUs. However, the NPAG algorithm takes into account a balanced SINR by means of inter-cell power game. Moreover, the power allocation is performed according to a threshold SINR, which enables to meet the requirement service and reduces the transmit power in the cell-edge. This additional power can be then transmitted in the cell-center.

Figure 4 shows the blocking rate for the FPA algorithm and the NPAG algorithm. It can be seen that the blocking rate is reduced further by the NPAG algorithm.

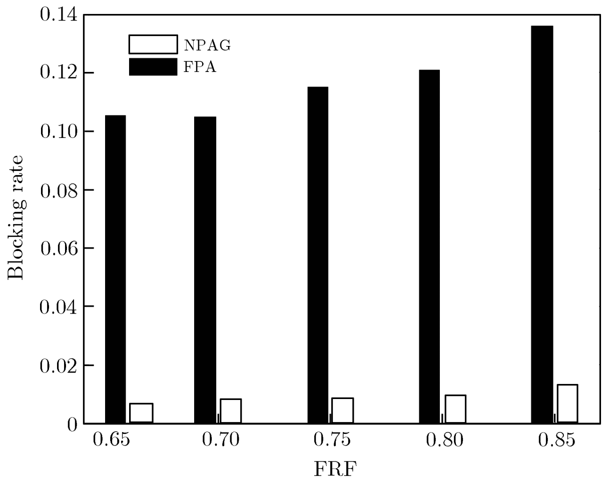

Figure 4 Blocking rate comparison in cell-edge.

For the full power in cell-edge, the redundant power brings about inter-cell interference to co-frequency users in other cells. Especially, as the growth of users in cell-edge and coordinated transmission is taken among different AUs, such interference also increases, making SINR stay in a low level. But the balanced SINR are established by the NPAG algorithm, which are also the Nash equilibrium in this power allocation game. Based on the improvement of SINR, the blocking rate is reduced.

5 Conclusions

As a new technology in LTE-Advanced, the coordinated transmission in CoMP becomes a challenge for the future mobile communication, which makes the network architecture modified to realize coordination relationship and centralized control.

Under this background, a novel power allocation algorithm named NPAG is proposed to mitigate inter-cell interference, based on game theory and the SINR exchange by cellular coordination. The inter-cell balanced SINR are taken as the objective function. On this basis, a utility function is established, and the optimum power allocation algorithm is achieved. Moreover, the existence and uniqueness of Nash equilibrium are proved for this power allocation game model.

Compared with the FPA algorithm, the numerical results show that the throughputs in both cell-center and cell-edge are improved, and the blocking rate in cell-edge is reduced too, showing that the NPAG algorithm outperforms the FPA algorithm. What is more, except for SFR scheme, this NPAG algorithm can also be applied to other frequency reuse schemes.

In the future, we should consider how to mitigate the inter-cell interference with some complex scenarios. Besides cellular coordination in this paper, we need to further consider some other specific approaches in CoMP, such as one user in cell-edge cooperatively served by several AUs, and establish game model for these approaches.

1 3GPP R1-082024. A discussion on some technology components for LTE-Advanced, May, 2008
2 3GPP R1-083050. Inter-eNB and Intra-eNB Schemes for CoMP in LTE-Advanced, Aug, 2008
3 3GPP R1-082469. LTE-Advanced Coordinated Multipoint transmission/reception, June, 2008
4 3GPP TR25.814. Physical layer aspects for evolved UTRA. 2006
5 3GPP R1-050738. Interference mitigation considerations and results on frequency reuse. Siemens, Sept 2005
6 3GPP R1-050764. Inter-cell interference handling for E-UTRA. Erics-son, Sept 2005
7 3GPP R1-083049. Consideration on CoMP for LTE-Advanced, Aug., 2008
8 Wang L, Yue Y, Schulz E, et al. Resource allocation in multi-cell OFDM systems based on noncooperative game. In: IEEE Proceedings of PIMRC, Helsinki, Finland, 2006. 1–5
9 Fudenberg D, Tirole J. Game Theory. Cambridge, Massachusetts: The MIT Press, 1991
10 Koskie S, Gajic Z. A Nash game algorithm for SIR-based power control in 3G wireless CDMA networks. IEEE/ACM Trans Network, 2005, 13(5): 1017–1026
11 3GPP R1-050507. Soft frequency reuse scheme for UTRAN LTE. Huawei, May 2005
12 Xu K, Tao X, Wang Y, et al. Inter-cell packet scheduling in OFDMA wireless network. In: IEEE Proceedings of VTC, Dublin, Ireland, 2007. 3115–3119
13 Baum D, Hansen J, Salo J, et al. An interim channel model for beyond-3G systems, In: Proc IEEE VTC'05, Stockholm, Sweden, May 2005
14 3GPP R1-050896. Description and simulation of interference management technique for OFDMA based EUTRA downlink evaluation. 2005