# Journal of
# Software Engineering

ISSN 1819-4311

Academic
Journals Inc.

www.academicjournals.com

Journal of Software Engineering 10 (1): 138-146, 2016
ISSN 1819-4311 / DOI: 10.3923/jse.2016.138.146

# Power Allocation Scheme Based on Fairness for Multi-Base Station Cooperative Communication System

[1]Hu Guolong, [1]Jia Zhenghong, [1]Qin Xizhong, [2]Niu Hongmei, [2]Jiao Huadong and [2]Liu Hanxing

[1]School of Information Science and Engineering, Xinjiang University, Urumqi, 830046, China
[2]Subsidiary Company of China Mobile in Xinjiang, Urumqi, 830063, China

*Corresponding Author: Jia Zhenghong, School of Information Science and Engineering, Xinjiang University, Sheng Li Road, Tian Shan Section, Urumqi, Xinjing, China Tel: 0086-13899985599*

## ABSTRACT

In order to strike balance between the maximum achievable rate and fairness, a new strategy of power distribution is proposed, in the multi-base station cooperative communication system. A fairness factor is defined in this study, to measure the service fairness among different users. Power allocation was formulated as the maximization problem of dividing average maximum achievable rate for the whole users (average rate) by the fairness factor. This problem can be solved by application of Genetic Algorithm (GA). Numerical results show that the proposed scheme outperforms equal power allocation, in terms of average rate as well as fairness.

**Key words:** Multicell cooperation, power distribution, equality, genetic algorithm

## INTRODUCTION

With the development of mobile communications, it requires higher transmission rates, serves more users (Ues) and provide better quality of service (QoS). However, without the coordination among adjacent cells, the performance of cell edge users is degenerated by the Inter-Cell Interference (ICI). Therefore, multi-base station cooperative communication technologies must be adopted to mitigate the effects of ICI and improve users' QoS. For example, Coordinated Multi-point Transmission (CoMP) technique is considered for LTE-Advanced (LTE-A) as one of the key technologies (Tan *et al*., 2011). In CoMP, several cooperative base stations transmit multi-streams to one user or multiple users simultaneously. In this way, it can effectively improve cell-edge user throughput (Matsuo *et al*., 2012), as well as the performance of the whole cellular network. The performance of a multi-base station cooperative communication system is closely related to the strategy of resource allocation. And power allocation is an important part of resource allocation (Wang *et al*., 2012). Therefore, how to distribute the power of several base stations (BSs) more effectively and reasonably has very important practical significance (Zakhour and Hanly, 2012). In the study Phuyal *et al*. (2012), an optimal power allocation scheme is proposed based on the minimum total transmission power in multi-base station cooperative communication system. In the study of Xiao *et al*. (2013), the authors present a power allocation strategy which aimed at maximizing the capacity of multi-base station cooperative communication system. The emphasis of above researches is to improve the overall performance of the system, ignoring the fairness between different users. In the study of Xiao *et al*. (2014), the authors take into account the fairness of users, put forward a power allocation method which make all users have equal signal to interference plus noise ratio (SINR). There is no doubt that this absolutely fair power allocation plan reduces the whole performance of multi-base station cooperative communication system. In this study, a new power distribution strategy was proposed which not only raise the whole performance of the system but also ensure the fairness of different users.

## MATERIALS AND METHODS

**System model:** In multi-base station cooperative communication system (Hardjawana *et al*., 2009; Ng *et al*., 2008), there are M BSs which transmit to N MSs. Each BS and MS are equipped with only one antenna. According to a certain rule, all BSs are scattered throughout the coverage area and connect to the central control unit by high-speed transmission medium, such as optical fiber. Each user can receive signals from several different BSs at the same time. Supposes wireless channel is Rayleigh fading channel, the received signal $Y_u$ at UE u can be expressed as (Xiao *et al*., 2013):

$$Y_u = \sum_{b\in Cu} h_{b,u}\sqrt{P_{b,u}}\,x_{b,u} + \sum_{j\in nCu}\sum_{k=1,k\neq u}^{U} h_{j,u}\sqrt{P_{j,k}}\,x_{j,k} + n_0 \tag{1}$$

where, the first item is the available signal, the second item is interference signal, n0 is the additive white Gaussian noise (AGWN), whose average is 0 and variance is $\sigma$. Cu is the cooperating set of UE u. The nCu is the complementary set of Cu. The $h_{b,u}$ is the channel matrix from BS b to UE u. $x_{b,u}$ is the signal transmitted from BS b to UE u. $P_{b,u}$ is the power transmitted from BS b to UE u. If BS b do not communicate with UE u, $P_{b,u} = 0$.

Supposes all BSs can accurately estimate the channel state information. $G_{b,u}$ is the channel gain from BS b to UE u. According to Eq. 1, the signal to interference plus noise ratio ($SINR_u$) of the u-th UE can be formulated as:

$$SINR_u = \frac{\sum_{b\in Cu} G_{b,u}P_{b,u}}{\sigma^2 + \sum_{j\in nCu}\sum_{k=1,k\neq u}^{U} G_{j,u}P_{j,k}} \tag{2}$$

The maximum achievable rate (per unit bandwidth) of UE u can be written as (Zhang *et al*., 2013):

$$V_u = \log_2(1+SINR_u) \tag{3}$$

The sum rate of all UEs can be described as:

$$V = \sum_{u=1}^{U}\log_2(1+SINR_u) \tag{4}$$

The average rate of all users can be given by:

$$\overline{V} = \frac{V}{U} \tag{5}$$

The maximum rate of all UEs can be found to be:

$$V_{max} = \max(V_u, u = 1, 2, \cdots\cdots, U) \tag{6}$$

The minimum rate of all UEs can be found to be:

$$V_{min} = \min(V_u, u = 1, 2, \cdots\cdots, U) \tag{7}$$

The fairness factor is:

$$\delta = \frac{V_{max}}{V_{min}} \tag{8}$$

If δ is greater, the difference between the maximum rate and the minimum rate is bigger, the fairness is worse. But δ is smaller, the difference between the maximum rate and the minimum rate is smaller, the fairness is better. Taking into account of fairness, the average rate of all UEs can be rewritten as:

$$Q = \frac{\overline{V}}{\delta} \tag{9}$$

The transmitted power of each BS is limited. Power allocation was formulated as follows:

$$\{P_{b,u},\ b = 1,\ 2,\ \cdots,\ M;\ u = 1, 2,\ \cdots, N\} = \arg \max_{P_{b,u}} Q \tag{10}$$

Subject to:

$$0 \le P_{b,u} \le P_b, b = 1, 2, \cdots, M;\ u = 1, 2,\ \cdots, N \tag{11}$$

And:

$$\sum_{i=1}^{U} P_{b,i} \le P_b, b = 1, 2, \cdots, M \tag{12}$$

where, the total transmitted power of BS b is $P_b$.

## Power allocation method

**Cooperating set selection strategy:** Compare the path loss of all BSs to UE u and find the BS with the minimum path loss. Then, set it as the main service BS:

$$BS_u^{master} = \min(PL_{b,u}, b = 1, 2,\ \cdots, M) \tag{13}$$

where, $BS_u^{master}$ is the main service BS of UE u, $PL_{b,u}$ is the path loss from BS b to UE u.

The path loss threshold is b. Compare the difference between $PL_u^{master}$ and $PL_{b,u}$ with b, get the cooperating set of UE u.

$$\begin{cases} b \in Cu, & \left|PL_u^{master} - PL_{b,u}\right| \leq \beta \\ b \in nCu, & \left|PL_u^{master} - PL_{b,u}\right| > \beta \end{cases} \tag{14}$$

where, $PL_u^{master}$ is the path loss of the main service BS of UE u, $G_u^{master}$ is the channel gain from UE u to $BS_u^{master}$. $P_u^{master}$ is the transmitted power from $BS_u^{master}$ to UE u. The signal to interference plus noise ratio of UE u can also be rewritten as:

$$SINR_u = \frac{G_u^{master}P_u^{master} + \sum\limits_{b\in Cu, b\neq BS_u^{master}} G_{b,u}P_{b,u}}{\sigma^2 + \sum\limits_{j\in nCu}\sum\limits_{k=1,k\neq u}^{U} G_{j,u}P_{j,k}} \tag{15}$$

So, the problem of power allocation can also be equivalent to:

$$\begin{aligned} \{P_{b,u},\ b=1,\ 2,\cdots,M;\ u=1,\ 2,\ \cdots,\ N\} &= \arg\ \max_{p_{b,u}} Q = \arg\frac{\overline{V}}{\delta} \\ &= \frac{1}{U}\sum_{u=1}^{U}\log_2(1+\frac{G_u^{master}P_u^{master} + \sum\limits_{b\in Cu, b\neq BS_u^{master}} G_{b,u}P_{b,u}}{\sigma^2 + \sum\limits_{j\in nCu}\sum\limits_{k=1,k\neq u}^{U} G_{j,u}P_{j,k}}) \Bigg/ \frac{V_{max}}{V_{min}} \end{aligned} \tag{16}$$

This problem has B×U unknowns, it is difficult to solve directly. To simplify the problem, the transmitted power of $BS_u^{master}$ can be as a reference. Then make power allocation in the cooperating set of UE u. So, the number of unknowns can be reduced to U. If BS b is in the cooperating set of UE u, $P_{b,u}$ can be written as (Xiao *et al*., 2014):

$$P_{b,u} = \frac{G_{b,u}}{G_u^{master}} \times P_u^{master}, b \in Cu \tag{17}$$

The signal to interference plus noise ratio of UE u can be rewritten as:

$$SINR_u = \frac{P_u^{master}[G_u^{master} + \sum\limits_{b\in Cu, b\neq BS_u^{master}} \frac{(G_{b,u})^2}{G_u^{master}}]}{\sigma^2 + \sum\limits_{j\in nCu}\sum\limits_{k=1,k\neq u}^{U} \frac{G_{j,u}G_{j,k}}{G_k^{master}} P_k^{master}} \tag{18}$$

The problem of power allocation can be simplified as:

$$\{P_{b,u}, b = 1, 2, \cdots, M;\ u = 1,\ 2, \cdots, N\} = \arg \max_{p_{b,u}} Q = \arg \frac{\overline{V}}{\delta}$$
$$= \frac{1}{U}\sum_{u=1}^{U} \log_2 \left(1 + \frac{P_u^{master}[G_u^{master} + \sum\limits_{b\in Cu, b\neq BS_u^{master}} \frac{(G_{b,u})^2}{G_u^{master}}]}{\sigma^2 + \sum\limits_{j\in nCu} \sum\limits_{k=1,k\neq u}^{U} \frac{G_{j,u}G_{j,k}}{G_k^{master}} P_k^{master}}\right) \Bigg/ \frac{V_{max}}{V_{min}} \tag{19}$$

This power allocation problem is a nonlinear optimization problem, it is difficult to solve directly. So, this problem was solved using GA (genetic algorithms).

**Genetic algorithms:** GA are stochastic global optimization methods oriented using both the concepts of natural selection as well as genetics and use three genetic operators i.e., selection, crossover and mutation, to explore and exploit the solution space. GA has been used broad in various fields, such as the non-linearity (Binelo *et al*., 2011). So we solve this problem was solved using GA (genetic algorithms) in Eq. 19.

**Initial population design:** If using the method of the binary encoding, it will cause some problem, such as more computation, lower accuracy and longer computing time and so on. In order to overcome the shortcoming of binary code, we use the decimal which can carry on the code directly. Real code can reduce the length of string code. Moreover, regarding the optimized question of continuous variable, real number expression has more accuracy of computation and will not produce the influence to the encoding method. The real-code string representation was proposed for candidate solution and then generate initial population randomly. An individual can be defined as:

$$\{P_1^{master}, P_2^{master}, \cdots, P_U^{master}\} \tag{20}$$

**Fitness function:** Once the population has been formed at each generation, the individual fitness has to be evaluated. The design of fitness function should reflect the object of the presented problem and it is the basis for selection operation. In this study we should get the maximum of objective function, so take the objective function as the fitness function. Fitness function can be expressed as:

$$F = \frac{\overline{V}}{\delta} \tag{21}$$

**Selection design:** Generally speaking, the selection strategy will affect the algorithm performance and the result. This study has used the roulette wheel selection strategy which combined the fitness proportion method with the best individual preservation method. Roulette wheel selection strategy is the most foundation and the most commonly used selection method at present genetic algorithm.

Supposes the population size is N, the fitness value of individual j is $F_i$, the selected probability $p_i$:

$$p_i = \frac{F_i}{\sum_{j=1}^{N} F_j} \tag{22}$$

**Crossover design:** Crossover can preserve excellent genes from their parents and results in excellent new individuals, so the crossover strategy can greatly affect the convergence of the algorithm. In this study, two chromosomes were randomly selected, one is from the father's chromosome and another is from the mother's. Then, randomly select one bit and do the following operation.

Supposes the j-th bit of chromosome i is $a_{i,j}$ and the crossover operation of chromosome i and chromosome k on bit j can be expressed as:

$$\begin{aligned} a_{i,j} &= a_{i,j}(1-b) + a_{k,j}b \\ a_{k,j} &= a_{k,j}(1-b) + a_{i,j}b \end{aligned} \tag{23}$$

where, b ε[0, 1].

**Mutation design:** Mutation is a process to change the gene of a chromosome randomly. The purpose of mutation is to generate new individuals, increase population diversity, prevent the population from premature convergence to a suboptimal solution. Therefore, the mutation strategy is an important factor of influencing the global search ability of the algorithm. Single-point mutation strategy was used in this study. Supposes the j-th bit of chromosome i is $a_{i,j}$, the mutation operation of chromosome i on bit j can be expressed as:

$$a_{i,j} = \begin{cases} a_{i,j} + \left(a_{i,j} - a_{\max}\right) \cdot f(g), & r \ge 0.5 \\ a_{i,j} + (a_{\min} - a_{i,j}) \cdot f(g), & r < 0.5 \end{cases} \tag{24}$$

$$f(g) = r_1 \cdot (1 - g / G_{\max})^2 \tag{25}$$

where, $a_{\max}$ is the upper bound of $a_{i,j}$, $a_{\min}$ is the lower bound of $a_{i,j}$, g is the current iteration times, $G_{\max}$ is the maximum of iteration times and $r_1$ is chosen randomly in the interval [0, 1].

## RESULTS AND DISCUSSION

**Simulation model:** In the simulation system, multi-base Station Cooperative Communication System with 7 cells is considered. Users are uniformly distributed in each cell. The number of antennas at each BS is 1 and each user device is equipped with 1 antenna. The parameters and setting used in the simulation are shown in Table 1. Here, we considered three different cases in this simulation study:

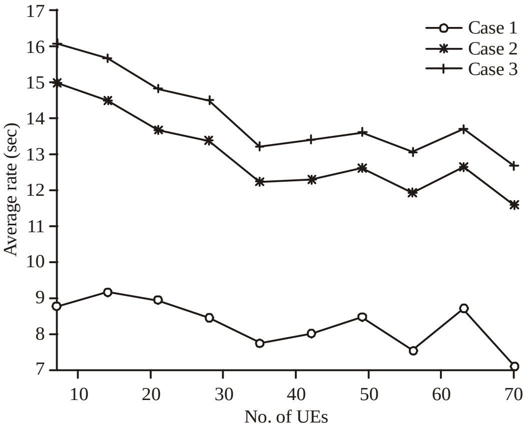

Fig. 1: Average rate comparison

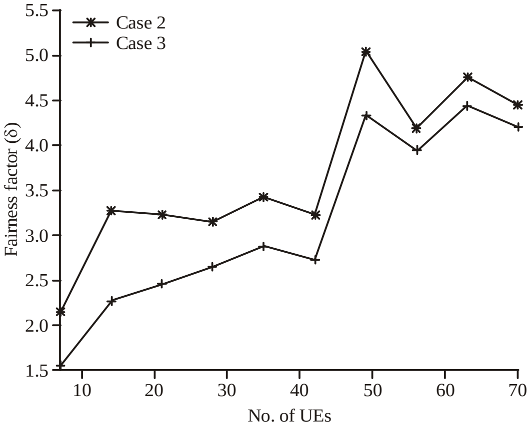

Fig. 2: Fairness factor comparison

- **Case 1:** Equal power allocation in conventional cellular system. This model is from Grandhi *et al.* (1993)
- **Case 2:** Equal power allocation in multi-base station cooperative communication system (Xiao *et al.*, 2014)
- **Case 3:** The present proposed approach

**Strategy performance analysis:** In this study, the performance of present proposed approach was composed with Case 1 and Case 2. Figure 1 shows how the average rate changes under different number of users. We can see when the number of users increase from 7-70, the average rate of Case 3 is greater than that of Case 1 and Case 2. When the number of users is 70, the average rate of Case 1, Case 2 and Case 3 are 7.10, 11.56 and 12.65 bit $\sec^{-1}$ $Hz^{-1}$. It is obvious that our work outperforms Case 1 and Case 2 in terms of average rate.

In Fig. 2, the simulation results of fairness factor of our proposed approach are compared with Case 2. From Fig. 2, it was known that as the number of users is increasing, the fairness factor of Case 3 is always less than Case 2. In Table 2, we give the fairness factor of Case 1.

Table 1: Simulation parameter

| Parameters | Value |
|---|---|
| Inter eNodeB distance (m) | 200 |
| eNodeB TX power (dBm) | 46 |
| Noise power density (dBm) | -96 |
| Pathloss model (g(R[km])[dB]) | 128.1+37.6l |
| β (dB) | 40 |
| Crossover probability | 0.6 |
| Mutation probability | 0.03 |

Table 2: $\delta$ in Case 1

| UEs' No. | δ |
|---|---|
| 7 | 23 |
| 14 | 431 |
| 21 | 199 |
| 28 | 562 |
| 35 | 623 |
| 42 | 10200 |
| 49 | 2468 |
| 56 | 11574 |
| 63 | 2851 |
| 70 | 2629 |

Comparing Fig. 2 with Table 2, it can be seen that the fairness factor of Case 1 is far greater than that of Case 2 and Case 3. When the number of users is 70, the fairness factor of Case 1, Case 2 and Case 3 is 2629.72, 4.43 and 4.19. So, the present proposed approach surpasses is superior to Case 1 and Case 2 in the aspect of fairness. In conclusion, our proposed strategy can improve average rate as well as equity.

## CONCLUSION

Fairness among users is significant for mobile communication system. We proposed a new strategy of power distribution to ensure user fairness. Simulation results are presented to demonstrate that the performance of our proposed approach is superior to equal power allocation in conventional cellular system and equal power allocation in multi-base station cooperative communication system, both on average rate and on fairness. When the number of users are 70, compare our proposed approach with other two strategies, users' average rate increases by 5.55 and 1.09 bit $\text{sec}^{-1}$ $\text{Hz}^{-1}$; fairness factor decreases by 2625.53 and 0.24.

## ACKNOWLEDGMENT

This study was supported by the Foundation of China Mobile Communications Corporation Xinjiang Co. Ltd. Research and Development Project under contract No. XJM2013-2788.

## REFERENCES

Binelo, M.O., A.L.F. de Almeida and F.R.P. Cavalcanti, 2011. MIMO array capacity optimization using a genetic algorithm. IEEE Trans. Veh. Technol., 60: 2471-2481.

Grandhi, S.A., R. Vijavan, D.J. Goodman and J. Zander, 1993. Centralized power control in cellular radio systems. IEEE Trans. Veh. Technol., 42: 466-468.

Hardjawana, W., B. Vucetic and Y.H. Li, 2009. Multi-user cooperative base station systems with joint precoding and beamforming. IEEE J. Sel. Top Signal Process., 3: 1079-1093.

Matsuo, D., R. Rezagah, G.K. Tran, K. Sakaguchi and K. Araki *et al*., 2012. Shared remote radio head architecture to realize semi-dynamic clustering in CoMP cellular networks. Proceedings of the IEEE Globecom Workshops, December 3-7, 2012, Anaheim, CA., pp: 1145-1149.

Ng, B.L., J.S. Evans, S.V. Hanly and D. Aktas, 2008. Distributed downlink beamforming with cooperative base stations. IEEE Trans. Inform. Theory, 54: 5491-5499.

Phuyal, U., S.C. Jha and V.K. Bhargava, 2012. Joint zero-forcing based precoder design for QoS-aware power allocation in MIMO cooperative cellular network. IEEE J. Sel. Area Commun., 30: 350-358.

Tan, Z.G., W.A. Zhou, C. Wei, S. Chen and Y.J. Xu, 2011. A dynamic cell selection scheme based on multi-object for CoMP DL in LTE-A. Proceedings of the IET International Conference on Communication Technology and Application, October 14-16, 2011, Beijing, China, pp: 248-252.

Wang, D., Z.Q. Li and X. Wang, 2012. Joint optimal subcarrier and power allocation for wireless cooperative networks over OFDM fading channels. IEEE Trans. Veh. Technol., 61: 249-257.

Xiao, H.L., P. Wang, S. Ouyang and M.Z. Li, 2013. Power allocation scheme based on system capacity maximization for multi-base station cooperative communication. J. Beijing Univ. Post Telecommun., 36: 93-97.

Xiao, H.L., P. Wang, Z.P. Nie and S. Ouyang, 2014. Power allocation scheme based on genetic algorithm for multi-base station cooperative communication. J. Univ. Electr. Sci. Technol. China, 43: 26-30.

Zakhour, R. and S.V. Hanly, 2012. Base station cooperation on the downlink large system analysis. IEEE Trans. Inform. Theory, 58: 2079-2106.

Zhang, X.J., Y. Sun, X. Chen, S.D. Zhou, J. Wang and N.B. Shroff, 2013. Distributed power allocation for coordinated multipoint transmissions in distributed antenna systems. IEEE Trans. Wireless Commun, 12: 2281-2290.