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Radio Resource Allocation in PD-NOMA based HCN System Considering CoMP Technology

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***Abstract*—In this paper, a downlink resource allocation (RA) optimization problem is investigated in heterogeneous cellular network (HCN) which is based on power domain - non-orthogonal multiple access (PD-NOMA) by considering coordinated multi-point (CoMP) technology. To assess the performance of the considered system a novel RA optimization problem is suggested. In order to solve the proposed optimization problem an iterative algorithm based on difference of concave functions (DC) method is applied. In each iteration the transmit power and subcarrier are updated separately and the iterative algorithm is continued until convergence. After applying the DC method, in order to solve the power allocation problem interior point algorithm is utilized, and to solve the subcarrier allocation problem the mesh adaptive direct search (MADS) algorithm is used. In simulation results, the effectiveness of the system model and optimization problem is investigated. As illustrated, by applying CoMP technology the performance of the system is improved by approximately** 16%.

Index Terms*– *Power domain - non-orthogonal multiple access (PD-NOMA), coordinated multi-point (CoMP), radio resource allocation (RA), difference of two concave functions (DC) approximation.

I. Introduction

THE request of high data rate cellular services is roughly doubling each year [1]. Consequently, advance technologies must be proposed to meet the wireless demands in fifth generation of cellular network (5G). Heterogeneous cellular networks (HCNs) which deploys low-power base stations (BSs) are proposed to improve the spectral efficiency (SE). HCN technology by dividing a large cell into smaller regions, decreases the distance among users and BSs. Therefore, it is possible to achieve higher system sum rate and less transmitted power. Another advanced technology which is introduced for responsiveness of high data rate wireless services growth, is power domain - non-orthogonal multiple access (PD-NOMA). PD-NOMA is an appropriate technology which is considered to be utilized as a part of the 5G mobile networks [3]. In a PD-NOMA transmitter, superposition coding (SC) technique is utilized for multiplexing the users transmitted signals in power domain, and at the receiver side, successive interference cancellation (SIC) method is applied for recovering the users transmitted data. Therefore, contrasted with typical orthogonal multiple access (OMA), PD-NOMA can improve SE significantly [4]. By utilizing coordinated multi-point (CoMP) technology in a HCN based system, the system performance can be improved. CoMP technology is proposed to retain inter-cell interference (ICI), and to enhance the users performance which could connect to multiple BSs simultaneously. In CoMP systems, a cluster of coordinating BSs are communicated with a central processing unit through backhaul network [5]. To synchronize the transmission of BSs, required information is shared between numerous BSs through a high speed backhaul links [6]. CoMP has more robustness against ICI and enhances data rate by various BSs working together [7].

To improve the system performance, CoMP technology and various resource allocation (RA) methods have been studied, recently [8], [9]. This combination can be utilized in HCN based systems to support the demands of high data rate services. In addition, PD-NOMA is an effective technique for increasing the achievable data rate.

Different RA schemes are investigated in OFDMA based HCN systems [12]–[15]. To investigate the RA in HCN, a unified strategy is proposed in [12]. Radio RA optimization problem for a HCN system is studied in [20]. PD-NOMA strategy is applied to utilize the benefits of the multi-carrier transmission technique that prepare high data rate in wireless channels [16]. A robust resource allocation algorithm for two types of traffic in systems based on PD-NOMA is investigated in [17]. Moreover, a new NOMA scheme is proposed for CoMP in [18]. Recently, the PD-NOMA performance in CoMP system is evaluated in [19].

The main contributions are summarized as follows:

- We recognize a downlink PD-NOMA based HCN system, where each user can receives its signals from different BSs simultaneously. The motivation behind this consideration is that PD-NOMA, HCN, and CoMP can improve the system SE.
- We propose a new RA optimization problem by considering CoMP technology, PD-NOMA and HCN which maximize the system sum rate. The constraints of the considered RA optimization problem are minimum rate requirement for each user, maximum available transmit power, and PD-NOMA constraints.
- In order to solve the proposed optimization problem, an

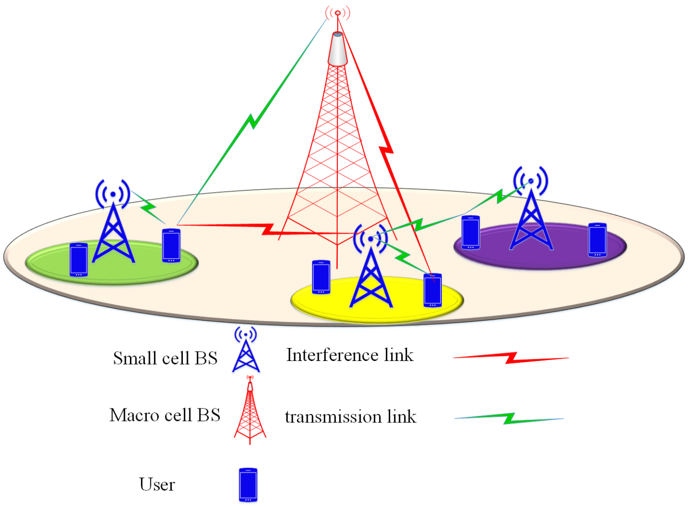

Fig. 1. Typical illustration of the considered system.

iterative algorithm is used. In this regard, we write the non convex functions in a difference of concave functions (DC) form, then DC approximation is applied to convert the optimization problem to a standard form of convex optimization.

The remaining organization of this paper is as follows: In Section II, we introduce both the system model and the problem formulation. In Section III, the SCA based algorithm is developed. In Section IV the complexity discussion is presented. In Section V the simulation results are introduced. At last, in Section VI, the paper is concluded.

II. SYSTEM MODEL AND PROBLEM FORMULATION

In this work, we recognize a downlink HCN based on PD-NOMA and CoMP technology which consists of a macro BS (MBS) and varied small BSs (SBSs). In addition, there are M users that are divided into two categories: users of SBSs and MBS. A typical illustration of the considered system is shown in Fig.1. Moreover, we consider that the total bandwidth is available in all the BSs. Therefore, as seen in Fig.1, the transmit power on each subcarrier in a BS crates interference on the other BSs which use the same subcarrier.

The channel coefficient between user m and BS f on subcarrier n is indicated with $h^f_{m,n}$, the power of BS f on subcarrier n to user m is expressed as $p^f_{m,n}$, and the subcarrier allocation to user m in BS f is indicated with the binary variable $\rho^f_{m,n} \in \{0, 1\}$, e.g., when the subcarrier n is allocated to user m in BS f, we have $\rho^f_{m,n} = 1$, and otherwise $\rho^f_{m,n} = 0$. Moreover, the sets of BSs and all subcarriers are shown by $\mathcal{F} = \{1, 2, ..., f\}$ and $\mathcal{N} = \{1, 2, ..., N\}$, respectively, where $f = 1$ refers to the MBS. Also, the set of users of BS f is denoted by $\mathcal{M}_f = \{1, 2, ..., M_f\}$. Consequently, from the above definitions, the achievable rate of user m from subcarrier n over BS f is formulated as $r^f_{m,n} = \log(1+\gamma^f_{m,n})$, $\gamma^f_{m,n}$ indicates the signal to interference plus noise ratio (SINR) of user m on subcarrier n over BS f, and is given by

$$\gamma^f_{m,n} = \frac{\sum\limits_{f\in\mathcal{F}} P^f_{m,n}\left|h^f_{m,n}\right|^2 \rho^f_{m,n}}{N_0 + I^f_{m,n}\,(\text{NOMA}) + I^f_{m,n}\,(\text{Intercell})}, \quad (1)$$

where N_0 shows the noise power, and $I^f_{m,n}$ (NOMA) and $I^f_{m,n}$ (Intercell) represent the PD-NOMA and the intercell interference, respectively, and are given by

$$I^f_{m,n}\,(\text{NOMA}) = \left|h^f_{m,n}\right|^2 \sum_{\left|h^f_{m,n}\right|^2 \le \left|h^f_{i,n}\right|^2} P^f_{i,n}\rho^f_{i,n}, \quad (2)$$

and

$$I^f_{m,n}\,(\text{Intercell}) = \sum_{\forall f'\in\mathcal{F}/\{f\}} \sum_{\forall i\in\mathcal{M}_{f'}} P^{f'}_{i,n}\rho^{f'}_{i,n}\left|h^{f'}_{i,n}\right|^2. \quad (3)$$

A. Necessary Conditions to Obtain Successful Interference cancellation

To obtain successful interference cancellation in each user, the following constraint must be applied [22], [23]

$$\rho^f_{m,n}\rho^f_{i,n}(\gamma^f_{m,n}(i) - \gamma^f_{i,n}(i)) \ge 0, \forall f \in \mathcal{F}, n \in \mathcal{N}, m, i \in \mathcal{M}_f,$$
$$|h^f_{i,n}|^2 \le |h^f_{m,n}|^2, i \ne m, \quad (4)$$

SINR of user m in subcarrier n over BS f at user i. With straightforward calculation, constraint (4) is written by

$$\rho^f_{m,n}\rho^f_{i,n}(\gamma^f_{m,n}(i) - \gamma^f_{i,n}(i)) = \rho^f_{m,n}\rho^f_{i,n}(-|h^f_{m,n}|^2 N_0 + |h^f_{i,n}|^2 N_0 - |h^f_{m,n}|^2 \sum_{j\in\mathcal{F}/\{f\}} \sum_{l\in\mathcal{M}_j} \rho^j_{l,n}p^j_{l,n}|h^j_{i,n}|^2 + |h^f_{i,n}|^2 \sum_{j\in\mathcal{F}/\{f\}} \sum_{l\in\mathcal{M}_j} \rho^j_{l,n}p^j_{l,n}|h^j_{m,n}|^2) \le 0. \quad (5)$$

Constraint (5) is a linear constraint in terms of power variables.

Consequently, the RA optimization problem is formulated as follows:

$$\max_{\boldsymbol{P},\boldsymbol{\rho}} \sum_{\forall f\in\mathcal{F}} \sum_{\forall m\in\mathcal{M}_f} \sum_{\forall n\in\mathcal{N}} r^f_{m,n}, \quad (6a)$$

$$\text{s.t.}: \quad C_1: \sum_{m\in\mathcal{M}_f} \sum_{n\in\mathcal{N}} \rho^f_{m,n}p^f_{m,n} \le p^f_{\max} \ \ \forall f \in \mathcal{F}, \quad (6b)$$

$$C_2: \sum_{m\in\mathcal{M}_f} \rho^f_{m,n} \le L, \ \ \forall n \in \mathcal{N}, f \in \mathcal{F}, \quad (6c)$$

$$C_3: 0 \le p^f_{m,n} \le p^{\text{mask}}, \ \ \forall m \in \mathcal{M}_f, n \in \mathcal{N}, f \in \mathcal{F}, \quad (6d)$$

$$C_4: \rho^f_{m,n} \in \{0, 1\}, \ \forall m \in \mathcal{M}_f, n \in \mathcal{N}, f \in \mathcal{F}, \quad (6e)$$

$$C_5: \sum_{\forall f\in\mathcal{F}} \sum_{\forall n\in\mathcal{N}} r^f_{m,n} \ge r^{\min}_m, \ \forall m \in \mathcal{M}_f, \quad (6f)$$

$$C_6: \rho^f_{m,n}\rho^f_{i,n}A^f_{m,i,n}(\boldsymbol{\rho}, \mathbf{p}) \le 0, \forall f \in \mathcal{F},$$
$$n \in \mathcal{N}, m, i \in \mathcal{M}_f, |h^f_{i,n}|^2 \le |h^f_{m,n}|^2, i \ne m, \quad (6g)$$

where constraint (6b) limits the maximum available power in each BS, (6c) indicates that subcarrier n can be assigned to at most L users, simultaneously, and (6f) expresses the minimum rate necessity.

Algorithm 1 ITERATIVE RADIO RA ALGORITHM

1: Initialization: initialize the iteration number $k = 0$ and $\boldsymbol{\rho}(0)$ and $\mathbf{P}(0)$.
2: Set $\boldsymbol{\rho} = \boldsymbol{\rho}(k)$, and apply DC approach,
3: Solve (16) and assign its solution to $\mathbf{P}(k+1)$,
4: Solve (7) and assign its solution to $\boldsymbol{\rho}(k+1)$,
5: If $\|\mathbf{P}(k) - \mathbf{P}(k-1)\| \leq \Theta$
finish,
otherwise
let $k = k+1$ and go back to the step 2

Due to the objective function, constraint (6f), and both integer and continuous variables, problem (6) is a non-convex optimization problem. Therefore, the solution methods of convex optimization problem can not be used directly.

III. SOLUTION ALGORITHM

In order to solve optimization problem (6), an iterative algorithm is exploited, where in each iteration, the transmit power and subcarriers are allocated separately, by applying the DC approximation method and MADS algorithm, respectively. An overview of the joint power allocation and subcarrier assignment algorithm is summarized in Algorithm 1. According to this algorithm, first, the transmit power and subcarrier assignment are initialized. Then, in each iteration, by considering fixed transmit power the subcarrier allocation is updated. Finally, by supposing fixed subcarrier, the power allocation is updated. It should be noted that the iterative algorithm is continued until the desired convergence.

A. Subcarrier Allocation

The subcarrier allocation optimization problem in each iteration is formulated as

$$\max_{\boldsymbol{\rho}} \sum_{\forall f \in \mathcal{F}} \sum_{\forall m \in \mathcal{M}_f} \sum_{\forall n \in \mathcal{N}} r^f_{m,n}, \tag{7}$$

$$\text{s.t.}: \quad C_1, C_2, C_4, C_5. \tag{8}$$

This optimization problem can be solved by MADS algorithm since it is an integer non-linear programming (INLP). Some available solvers such as NOMAD [25] can be used to apply MADS.

B. Power Allocation

The power allocation optimization problem considering fixed subcarrier allocation in each iteration, is given by

$$\max_{\boldsymbol{P}} \sum_{\forall f \in \mathcal{F}} \sum_{\forall m \in \mathcal{M}_f} \sum_{\forall n \in \mathcal{N}} r^f_{m,n}, \tag{9}$$

$$\text{s.t.}: \quad C_1, C_3, C_5, C_6.$$

The power allocation optimization problem is a non-convex optimization problem due to the non-covexity of both the objective function and the constraint $C5$. As a result, a SCA approach is utilized to approximate it to a convex optimization problem. Then, the interior point method is applied.

For any m and f the achievable rate is exploited by

$$\sum_{n \in \mathcal{N}} r^f_{m,n} = \tag{10}$$

$$\sum_{\forall n \in \mathcal{N}} \log\Bigg(\sum_{\forall f \in \mathcal{F}} P^f_{m,n} \big|h^f_{m,n}\big|^2 \rho^f_{m,n} + N_0 + I^f_{m,n}(\text{NOMA}) + I(\text{Intercell})\Bigg) - \log\left(I^f_{m,n}(\text{NOMA}) + I^f_{m,n}(\text{Intercell}) + N_0\right),$$

where it is difference of two concave functions. The DC method [14] is exploited to approximate the non-concave function (10) by a concave one. To this end, the objective function is written as

$$\sum_{\forall f} \sum_{\forall m} \left(G\left(\mathbf{P}^f_m\right) - H\left(\mathbf{P}^f_m\right)\right), \tag{11}$$

where

$$G\left(\mathbf{P}^f_m\right) = \sum_{\forall n} \log\Bigg(\sum_{\forall f} P^f_{m,n} \big|h^f_{m,n}\big|^2 \rho^f_{m,n} + N_0 + I^f_{m,n}(\text{NOMA}) + I^f_{m,n}(\text{Intercell})\Bigg), \tag{12}$$

and

$$H\left(\mathbf{P}^f_m\right) = \sum_{\forall n} \log\left(I^f_{m,n}(\text{NOMA}) + I^f_{m,n}(\text{Intercell}) + N_0\right). \tag{13}$$

By applying a linear approximation, $H\left(\mathbf{P}^f_m\right)$ can be presented by

$$H\left(\mathbf{P}^f_m\right) \simeq \tilde{H}\left(\mathbf{P}^f_m\right) = H\left(\mathbf{P}^f_m(t-1)\right) + \nabla^T H\left(\mathbf{P}^f_m(t-1)\right)\left(\mathbf{P} - \mathbf{P}(t-1)\right), \tag{14}$$

where the number of entries of the vector $\nabla^T H\left(\mathbf{P}^f_m\right)$ is equal to $N \times M$ and its entry is given by

$$\nabla^T H\left(\mathbf{P}^f_m\right) = \begin{cases} 0, & \left|h^f_{j,n}\right|^2 \leq \left|h^f_{m,n}\right|^2, \; f' = f, \; \forall i \in \mathcal{M}_{f'} \\ \dfrac{\rho^{f'}_{k,n}\left|h^{f'}_{k,n}\right|^2}{I^f_{m,n}(\text{NOMA}) + I^f_{m,n}(\text{Intercell}) + N_0}, & \text{O.W.} \end{cases} \tag{15}$$

Consequently, by applying DC method, a standard convex optimization problem form of the power allocation optimization problem is formulated as follows

$$\max_{\boldsymbol{P}} \sum_{\forall f \in \mathcal{F}} \sum_{\forall m \in \mathcal{M}_f} \left(G\left(\mathbf{P}^f_m\right) - \tilde{H}\left(\mathbf{P}^f_m\right)\right), \tag{16a}$$

$$\text{s.t.}: \quad C_1, C_3, \tag{16b}$$

$$\sum_{\forall f \in \mathcal{F}} \left(G\left(\mathbf{P}^f_m\right) - \tilde{H}\left(\mathbf{P}^f_m\right)\right) \geq r^{\max}_m, \; \forall m \in \mathcal{M}_f. \tag{16c}$$

To solve the optimization problem (16), the interior point method is applied. To apply the interior point algorithm, several available software can be used. In this paper, the CVX solver is used [26].

IV. Complexity discussion

In this section the complexity of solution algorithm and receivers are investigated.

A. Complexity of the solution algorithm

As explained before, in order to solve the considered optimization problem an iterative algorithm is utilized where each iteration has two steps, the power allocation step and the subcarrier allocation step. To solve the power allocation step, interior point method is applied and its complexity order is given by

$$\mathcal{O}(\frac{\log(\frac{\Psi}{t\mu})}{\log(\xi)}), \quad (17)$$

where Ψ represents the total number of the power allocation problem constraints and in our work $\Psi = 2F + M_f(1+NF)$, $0 < \xi \ll 1$ is the stopping criterion, t is the accuracy initial point, and μ is used to update the accuracy of interior method [30]. Moreover, the subcarrier allocation problem complexity is related to the number of variables and constraints since the NOMAD solver is used where the total number of variables is equal to $M_f NF$ and the number of constraints of the subcarrier allocation problem is equal to $F(1+N+NM_f)+M_f$ [27]- [29].

B. Complexity of the SIC based receiver

If we consider that NS subcarriers are assigned to a use, by applying the minimum mean square error (MMSE) detector, the complexity order of SIC receiver is approximately given by $\mathcal{O}((L^3+2L^2)(NS)(L-1))$ [31].

V. Simulation results

Here, the downlink radio RA optimization problem for the proposed system model is investigated with numerical results. The simulation parameters are supposed as: $N = 32$, $L = 3$, $p_0^{\max} = 42$ dBm (total transmit power of the MBS), $p_m^{\max} = 23$ dBm, $\forall m \in \mathcal{M}/\{0\}$ (total transmit power of each SBS), $N_0 = -174$ dBm/Hz, and $h_{m,n}^f = \chi_{m,n}^f (d_m^f)^\psi$ where d_m^f is the distance from user m to BS f, $\psi = 2$ is the path loss exponent and $\chi_{m,n}^f$ is an exponential random variable. Fig. 2 and Fig. 3 show the system sum rate versus the number of users and the maximum total transmit power, respectively. As can be seen, by using CoMP technology the system performance is improved by approximately 16%. Moreover, Fig. 4 shows the system sum rate versus the total transmit power for different values of L. Clearly, can be seen that by increasing either the total transmit power or the value of L, the system sum rate increases.

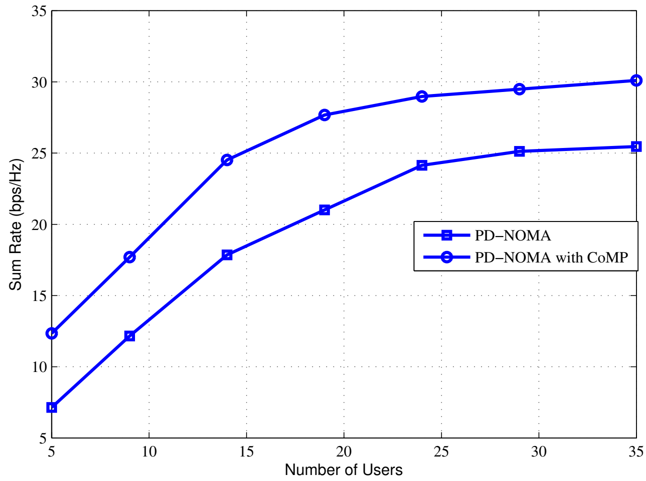

Fig. 2. System sum rate versus the number of users ($|F| = 5$).

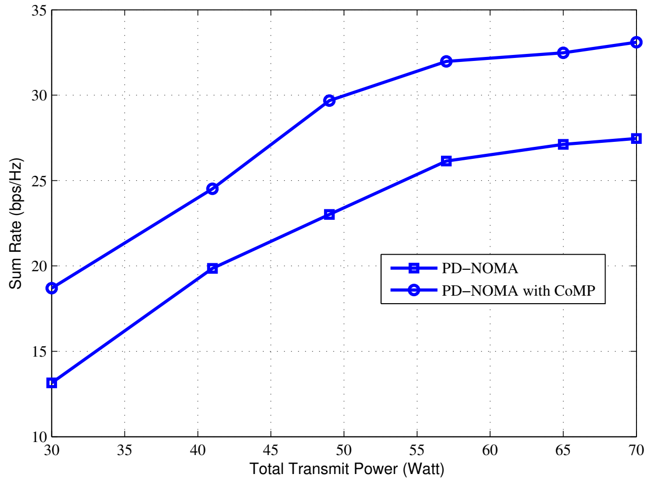

Fig. 3. System sum rate versus the maximum transmit power ($|F| = 5$).

VI. Conclusion

In this work, we studied a downlink radio RA in PD-NOMA based HCN system considering CoMP technology. The main aim of the proposed RA optimization problem was maximizing the system sum rate with maximum available transmit power, minimum rate requirement for each user, and PD-NOMA constraints. To solve the proposed RA optimization problem, we used the DC approximation based iterative algorithm where in each iteration, power and subcarrier are allocated separately. As the simulation results show, CoMP technology can increase the system sum rate by approximately 16%.

References

[1] Qualcomm, "Rising to meet the 1000 mobile data challenge," *Qualcomm*, Oct. 2012.
[2] Z. Xu, C. Yang, G. Li, Y. Liu, S. Xu, "Energy-efficient CoMP precoding in heterogeneous networks," *IEEE Trans. Signal Proc.*, vol. 62, no. 4, pp. 1005–1017, 2014.
[3] ICT-317669 METIS project, "Proposed solutions for new radio access," *METIS*, Deliverable D.2.4, Feb. 2015.
[4] NTT DOCOMO, "5G radio access: requirements, concept and technologies," *NTT DOCOMO, Inc.*, 5G Whitepaper, July 2014.
[5] I. Bukar, and F. Ali, "Subcarrier Multiplexing in LTE-CoMP OFDMA," *in Proc. IEEE VTC Spring*, pp. 1–5, 2015.
[6] M. Sawahashi, Y. Kishiyama, A. Morimoto, D. Nishikawa, and M. Tanno, "Coordinated multipoint transmission/reception techniques for LTE-advanced," *IEEE Trans. Wireless Commun.*, vol. 17, no. 3, pp. 26–34, Jun. 2010.

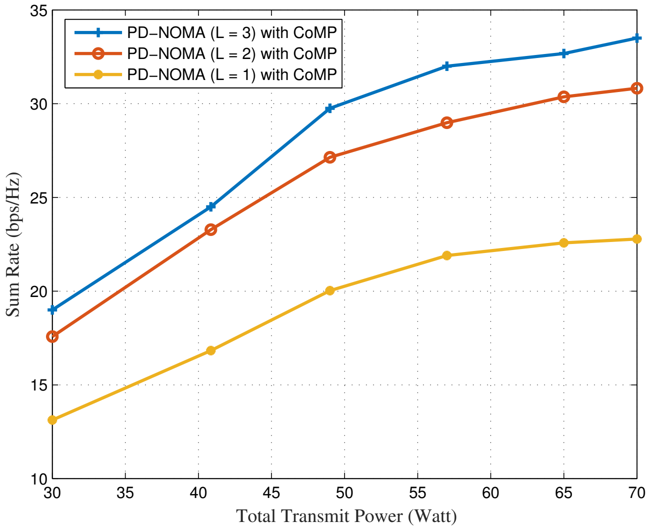

Fig. 4. System sum rate versus the maximum transmit power for different values of L ($|F| = 5$).

[7] D. Choi, D. Lee, and J. H. Lee, "Resource allocation for CoMP with multiuser MIMO-OFDMA," *IEEE Trans. Veh. Technol.*, vol. 60, no. 9, pp. 4626–4632, Nov. 2011.
[8] S. Kaviani and W. A. Krzymien, "Sum rate maximization of MIMO broadcast channels with coordination of base stations," *in Proc. IEEE WCNC*, pp. 1079–1084, Apr. 2008.
[9] R. Zhang, "Cooperative multi-cell block diagonalization with per-basestation power constraints," *IEEE J. Sel. Areas Commun.*, vol. 28, no. 9, pp. 1435–1445, Dec. 2010.
[10] S. Parkvall, E. Dahlman, A. Furuskr, Y. Jading, M. Olsson, S. Wnstedt and K. Zangi, "LTE-advanced - evolving LTE towards IMT advanced," *in Proc. IEEE VTC-F08*, pp. 1–5, Sep. 2008.
[11] T. A. Le and T. Gherkar, M. R. Nakhai and K. Navaie, "Symbol timing offset mitigation in OFDMA-based CoMP utilizing position aware transmission," *in Proc. IEEE VTC Spring*, 2015.
[12] D. Fooladivanda, C. Rosenberg, "Joint resource allocation and user association for heterogeneous wireless cellular networks," *IEEE Trans. Wireless Commun.*, vol. 12, no. 1, pp. 248–257, 2013.
[13] W. C. Cheung, T. Q. S. Quek and M. Kountouris, "Throughput optimization, spectrum allocation, and access control in two-tier femtocell networks," *IEEE J. Sel. Areas Commun.*, vol. 30, no. 3, pp. 561–574, 2012.
[14] D. T. Ngo, S. Khakurel, T. Le-Ngoc, "Joint subchannel assignment and power allocation for OFDMA femtocell networks", *IEEE Trans. Wireless Commun.*, vol. 13, no. 1, pp. 342–355, 2014.
[15] L. B. Le, D. Niyato, E. Hossain, D. I. Kim and D. T. Hoang, "QoS-aware and energy-efficient resource management in OFDMA femtocells", *IEEE Trans. Wireless Commun.*, vol. 12, no. 1, pp. 180–194, 2013.
[16] A. Mokdad, P. Azmi, N. Mokari, "Radio Resource Allocation for Heterogeneous Traffic in GFDM-NOMA Heterogeneous Cellular Networks" *IET Communications*, vol. 10, no. 12, pp. 1444–1455, 2016.
[17] A. Mokdad, M. Moltafet, P. Azmi, N. Mokari, "Robust Radio Resource Allocation for Heterogeneous Traffic in PD-NOMA-based Cellular Systems" *accepted in Proc. IEEE ICEE*, 2017.
[18] J. Choi, Non-Orthogonal Multiple Access in Downlink Coordinated Two-Point Systems," *IEEE Commun. Lett.*, vol. 18, no. 2, pp. 313–316, Feb. 2014.
[19] Y. Tian, A. R. Nix, M. Beach, "On the Performance of Opportunistic NOMA in Downlink CoMP Networks," *IEEE Commun. Lett.*, vol. 20, no. 5, pp. 998–1001, May 2016.
[20] G. Cao, D. Yang, X. Zhu and X. Zhang, "A joint resource allocation and power control algorithm for heterogeneous network," *in Proc. IEEE ICT*, pp. 1–5, Apr. 2012.
[21] H. Zhang, C. Jiang, N. Beaulieu, X. Chu, X. Wen, and M. Tao, "Resource allocation in spectrum-sharing OFDMA femto-cells with heterogeneous services," *IEEE Trans. Wireless Commun.*, vol. 62, no. 7, pp. 2366–2377, July 2014.
[22] Y. Sun, D. W. K. Ng, Z. Ding and R. Schober, "Optimal Joint Power and Subcarrier Allocation for Full-Duplex Multicarrier Non-Orthogonal Multiple Access Systems," in *IEEE Trans. on Commun.*, vol. 65, no. 3, pp. 1077–1091, Jan. 2017.
[23] D. Tse and P. Viswanath, "Fundamentals of wireless communication," *Cambridge university press*, 2005.
[24] G. Dartmann, W. Afzal, X. Gong, and G. Ascheid, "Joint optimization of beamforming, user scheduling, and multiple base station assignment in a multicell network," *in proc. IEEE WCNC*, pp. 209–214, 2011.
[25] http://www.i2c2.aut.ac.nz/Wiki/OPTI/index.php/Solvers/NOMAD.
[26] I. CVX Research, "CVX: Matlab software for disciplined convex programming, version 2.0," http://cvxr.com/cvx, Aug. 2012.
[27] S. Le Digabel, "Algorithm xxx: NOMAD: Nonlinear Optimization with the MADS algorithm," 2010.
[28] C. Audet and J. E. Dennis Jr, "Mesh adaptive direct search algorithms for constrained optimization," *SIAM J. on optimization*, vol. 17, no. 1, pp. 188–217, 2006.
[29] C. Audet, A. Ianni, S. Le Digabel and C. Tribes, "Reducing the number of function evaluations in mesh adaptive direct search algorithms," *SIAM J. on optimization*, vol. 24, no. 2, pp. 621–642, 2014.
[30] S. Boyd and L. Vandenberghe, "Convex Optimization," *Cambridge Univ. Press*, 2004.
[31] M. Moltafet, N. Mokari, M. R. Javan, and P. Azmi, "Comparison Study between NOMA and SCMA," arXive preprint arXiv:1702.01389.

