(IJACSA) International Journal of Advanced Computer Science and Applications,
Vol. 9, No. 6, 2018

Swarm Optimization based Radio Resource Allocation for Dense Devices D2D Communication

O. Hayat
1.NUML H-9 Islamabad, Pakistan.
Wireless Communication Center (WCC), Faculty of Electrical Engineering, Universiti Teknologi Malaysia

R. Ngah
Wireless Communication Center (WCC), Faculty of Electrical Engineering, Universiti Teknologi Malaysia

Siti Z. Mohd Hashim
Big Data Centre,
Faculty of Computing,
Universiti Teknologi Malaysia

***Abstract*—In Device to Device (D2D) communication two or more devices communicate directly with each other in the in-band cellular network. It enhances the spectral efficiency due to cellular radio resources (RR) are shared among the cellular users and D2D users. If the RR sharing is not legitimate properly, it causes interference and inefficient use. Therefore, management of RR between cellular users and D2D users is required to control the interference and inefficient use of RR. In D2D enabled cellular network, D2D users have a good signal to noise ratio (SNR) compared with cellular users due to the short distances and dedicated path. Using this advantage, an efficient RR allocation algorithm based on swarm optimization is proposed in this paper, that allows utmost spatial reuse in multi-users and OFDMA networks. The algorithm determines the required RR on the request of D2D users following the indicator variable. It enhances the capacity (Bit/Hz), overall system throughput and spectral efficiency with respect to sub-carriers in OFDMA networks. The performance of the proposed algorithm is evaluated via MATLAB simulations.**

Keywords*—*Device to device (D2D) communication; radio resources (RR) allocation; OFDMA networks; sub-channels and sub-carriers; cellular users and D2D users

I. INTRODUCTION

The Device to Device (D2D) communication in fourth-generation long-term evolution (4G LTE) focuses on public safety, but the potential advancements that can be given by D2D operation are not completely exploited yet [1]. D2D communication as an underlay to cellular system is viewed as one of the key advances for improving the performance of upcoming cellular systems. In 5G systems, it is anticipated that D2D operation will be locally coordinated as a component without bounds the 5G system. The fundamental potential gains by D2D including, capacity and throughput, low latency, availability and reliability and proximity services. All these gains can be achieved only using efficiently resources allocation and utilization. Collectively it is called radio resources (RR) allocation for D2D communication. In a cellular system, multiple devices exist with multiple services and operators. When many devices qualify for D2D, then who will provide the resources to accomplish D2D communication. It includes data channel, control channel and other cellular services without affecting the cellular users. The RR allocation in OFDMA cellular network has three scenarios i) cellular users to D2D users ii) D2D users to cellular users iii) D2D users to D2D users as presented in Fig. 1.

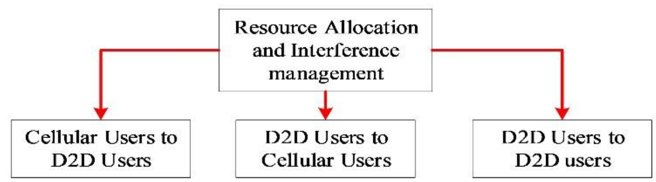

Fig. 1. Scenarios for radio resources allocation among D2D users and cellular users in the cellular system.

The fundamental thought of D2D communication is that suitable selected devices reuse the cellular resources to set up direct communication links [2]. Given conditions are that the D2D communication does not put an adverse effect on cellular users like interference and cellular users have right to use the resources freely. Despite its awesome potential in coverage and capacity, it has some challenges particularly RR allocation. The essential thought is to reuse cellular resources by enabling adjacent wireless devices to build up direct communication links. This idea does not just enhance the proficiency of spectrum utilization, yet additionally has an extraordinary potential for upgrading the system performance articulated in terms of system capacity, throughput, spectral efficiency, and end-to-end delays. There are two approaches for RR allocation: half duplex and full duplex. Conventionally an user equipment is equipped with a single antenna, therefore two orthogonal time stages are needed for individual transmission and reception in half-duplex. In first time stage, all users equipment should keep silent and listen from the base station on the downlink channel. In second time stage each device request for resources as cellular users or D2D users. Although this approach will not cause interference between cellular users and D2D users while degrading the RR reuse gain. To overcome this deficiency, full duplex OFDMA is an alternative and allows multi-users to use the same RR simultaneously [3].

To organize the system controlled D2D communication as an underlay to the cellular system, a network planner faces few difficulties, which mostly arise because of the absence of consistent channel information at the base stations. Efficient feedback is significant to get channel information. The channel information for cellular users at the serving base station can be acquired efficiently. Conversely, such information is not accessible for D2D channels. The reason is the division of the control plane from user/data plane because of the system controlled D2D communication. A quick outcome of this division is that D2D users can't specifically use pilot signals communicated by the base station in contrast to cellular users for estimation of D2D channels. Additionally, local transmission of the individual pilot signal by every D2D users is not possible and would not tackle the issue because of pilot contamination. Since techniques for overwhelming pilot contamination in D2D scenarios experience the ill effects of the requirement for expanded feedback and control overhead. Various formulations have been proposed for RR allocation, for example, proportional and max-min fairness, inelastic traffic, weighted fair queuing and convex optimization techniques [4].

D2D and RR allocation both are state of art and future research challenges. The emphasis is on D2D situations, for example, situations with normally low mobility where data offloading, improvement of network capacity, reduced latency and enhance data rates play a leading role. The attention will be on in-band underlay D2D communication, in which D2D utilizes similar resources of the spectrum from the cellular network. It is sensible to expect that RR allocation to D2D users must be accomplished in a distributed manner under entirely restricted channel information. In addition, it is of most extreme significant that immediate transmissions among devices are coordinated to guarantee that they don't detrimentally affect the performance of cellular users. Such coordination must include a cautious power allocation of D2D users to available RR, essentially utilized as downlink or uplink. This issue, which is hard to understand even in a centrally controlled system, is additionally provoked in a D2D setting by the requirement for distributed arrangements. Therefore, RR allocation model for multi-devices in OFDMA system is proposed for high data rate, energy efficiency and interference avoidance between cellular users and D2D users. With the D2D pair establishment, RR can be allocated to that pair for communication. After discovery, as discovered device receives a request for connection, RR is thus allocated to discoverer devices only. It allows the D2D pair to transmit and receive data over the same allocated channel. Swarm optimization is applied for RR allocation to minimize the interference between cellular users and D2D users. It enhances the system capacity, throughput, and frequency efficiency.

Rest of the paper is organized as follow: Section 2 explains the Radio resource allocation techniques for D2D users and the radio resource allocation model and results are discussed in Section 3. In the end, the paper is concluded in Section 4.

II. RR Allocation Techniques for D2D Users

There are two types of RR allocation techniques in in-band D2D communication: underlay and overlay as described in Fig. 2. The expansion of the D2D layer as an underlay to cellular systems postures new difficulties in term of interference control compare with ordinary cellular networks. RR allocation for D2D in underlay cellular network is proposed [5] based on joint scheduling. It controls the power to avoid the interference and maintain the QoS of D2D link, but the problem is accommodation of maximum users is quite difficult. RR allocation in mobility structure for underlay D2D is presented in [6] in which, RR are apportioned based on distance. When the distance is increased, channel allocation becomes problematic between D2D pair. A distance limit model for RR allocation is proposed in [7], in which RR are allocated cellular and D2D link based max-flow algorithm. It enhances the sum rate but creates interference. These difficulties originate from the reuse of radio resources among cellular users and D2D users, which make intra-cell interference.

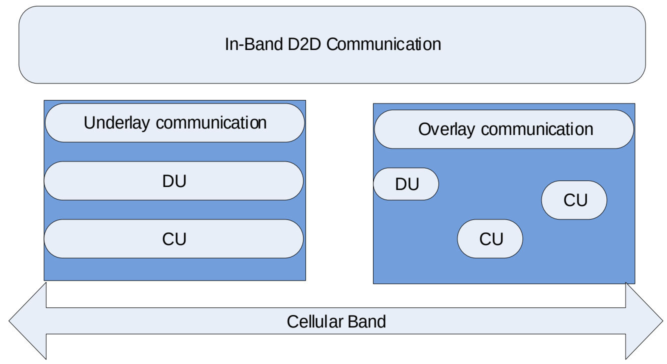

Fig. 2. In-band D2D radio resource distribution as an underlay and overlay.

Consequently, to exploit the advantages of D2D communication and accomplish an enhanced network performance over standard cellular networks, cautious RR allocation that considers both cellular users and D2D users is fundamental. RR allocation procedures for D2D underlay communication can be ordered relying upon the optimization metric [8]. RR allocation figures out which particular frequency and time resources ought to be allotted to each D2D and cellular links. RR allocation algorithms can be comprehensively grouped by the level of system control, centralized versus distributed, and the level of coordination between cells, single cell versus multi-cell [9]. Every cellular user in OFDMA is allocated to the sub-carriers and every sub-carrier is allocated by the network [10]. To facilitate an essential unit of RR allocation in OFDMA, sub-carriers are characterized as a sub-channel. Contingent upon how the sub-carriers are allocated to build each sub-channel.

The RR allocation techniques are grouped into a random type, comb type and block type as is appeared in Fig. 3. To avoid the wastage of RR, random type RR allocation is considered in this research. In a random type RR allocation, each sub-channel is comprised of a set of sub-carriers allocated randomly over the whole spectrum. If random type sub-channels are utilized, then interference is incorporated to accomplish the adversity gain. For this situation, all pilots situated over the entire bandwidth might be utilized for channel estimation between cellular users and D2D users. This sort of sub-channels tends to normal out the channel quality over the entire band [11]. Therefore, it can oblige high mobility, anyhow, when the quality of each sub-carrier consistently differs from one frame to the next. In a D2D enabled cellular network, besides, it is helpful for decreasing the co-channel interference by haphazardly allocating sub-carriers such that the probability of sub-carrier interference among D2D users and cellular users decreases. In random type RR allocation, to avoid the interference between co-cells different random type allocation is performed as presented in Fig. 3 random type(a) and random type(b). In this research in-band underlay, RR resource allocation technique is considered. The RR allocation is generic and can be pragmatic to many systems [12] for example, multi-cast, ad-hoc and Wi-Fi network. Therefore, some successful solution is required for D2D communication enabled network in which optimization is required to minimize with delay and interference.

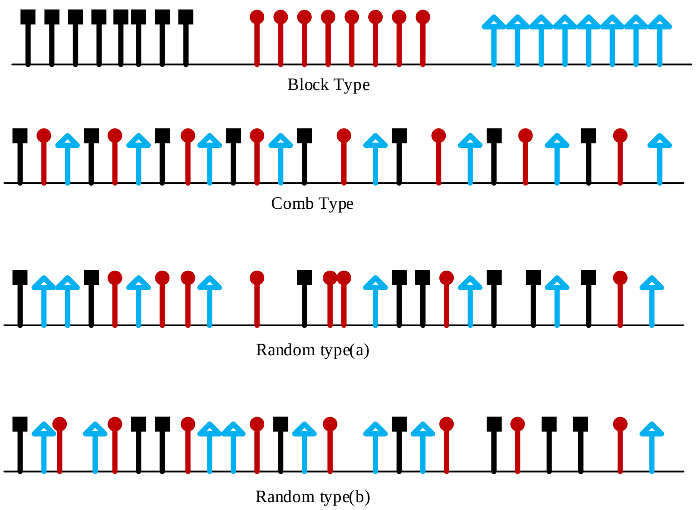

Fig. 3. In-band D2D radio resource distribution as an underlay and overlay.

III. Resources Allocation Model and Results

RR allocation depends on sub-channel and sub-carrier, whether they are centralized or localized. In D2D enabled the network utilizes the localized sub-channel and needs efficient RR allocation between D2D users and cellular users. The sub-channelization is classified into two classes adaptive and diversity sub-channel. There are three types of downlink diversity sub-channel according to usage partial, full and optional (partial or full) usage. It is totally depending on whether every sub-channel is built by scattered sub-carriers throughout the entire band or not. Similarly, in uplink, there is two types of diversity sub-channel partial and optional usage. Adaptive sub-channels are utilized in both downlink and up-link and in all kinds of the sub-channel comprises of 48 sub-carriers [13]. In this work OFDMA based LTE system is assumed. The basic difference between OFDM and OFDMA network is RR allocation on time domain in OFDM while frequency and time domain both in OFDMA to user equipment [14]. In OFDMA system, spatial RR are centrally allocated to D2D pair by the base station individually. In the RR allocation, the frequency is divided into sub-channel and time into slots. OFDMA makes grids of the channel which involve a sub-channel per slot. OFDMA system with a sub-carrier and sub-carrier selection is very important because of constraints between base station power and user equipment support as presented in result Fig. 4. Results elaborate that more sub-carriers lead more power and capacity from system model shown in Fig. 5.

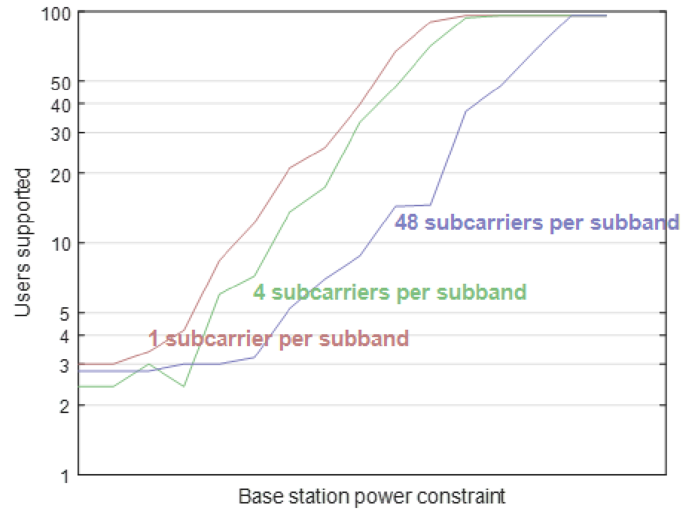

Fig. 4. User supported versus base station power constraints for different sub-carriers.

$$y = \boldsymbol{h}_{C1-B1}\mathbf{s} + n \tag{1}$$

where $\boldsymbol{h}_{C1-B1}$ is channel matrix of MIMO system patterned by $M_R \times M_T$.

$$\boldsymbol{h}_{C1-B1} = \begin{bmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,M_T} \\ h_{2,1} & h_{2,2} & \cdots & h_{2,M_T} \\ \vdots & \vdots & \ddots & \vdots \\ h_{M_R,1} & h_{M_R,2} & \cdots & h_{M_R,M_T} \end{bmatrix} \tag{2}$$

Let C-1 is cellular users and D-2 to D-5 are D2D users in a cell and these devices are transceiver devices as presented in Fig. 5. RR allocation is followed the following condition:

$$x_D^c = \begin{cases} 1 & \text{if D2D pair reuse the resources of } C1 \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

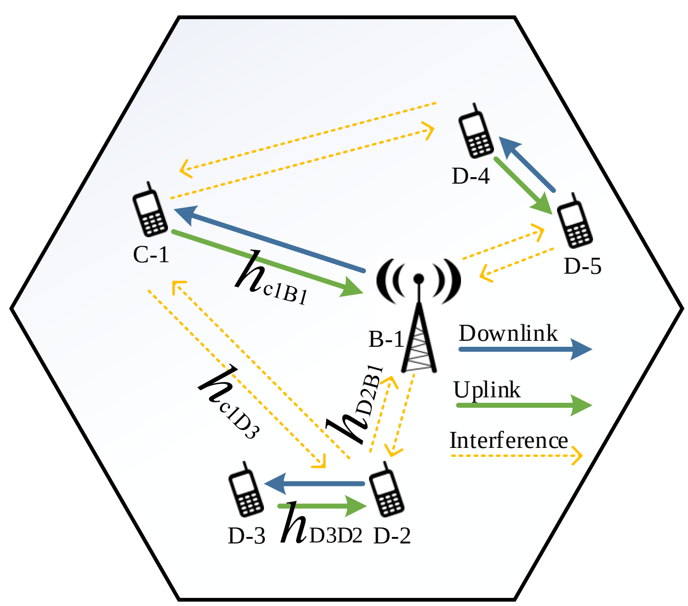

Fig. 5. RR system model in OFDMA single cell network.

x_D^c is indicator variable of cellular resources are allocated to D2D users. SINR of C-1 at base station B-1 is give as

$$\gamma_{C-1} = \frac{P_c \boldsymbol{h_{C1-B1}}}{N_0 + \sum_1^d x_D^c P_D \boldsymbol{h_{D2B1}^c}} \quad (4)$$

Where P_C and P_D are transmitted power of C-1 and D2D of D3D2 respectively. $\boldsymbol{h_{C1-B1}}$ is channel gain from cellular C-1 to base station B-1 and $\boldsymbol{h_{D2B1}^c}$ is channel gain of D-2 to B-1 when it is using cellular resources.

SINR at D2D of D3D2

$$\gamma_D = \frac{\sum_1^d x_D^c P_D \boldsymbol{h_{D3D2}^c}}{N_0 + \sum_1^d x_D^c P_c \boldsymbol{h_{C1D3}}} \quad (5)$$

$\boldsymbol{h_{D3D2}^c}$ *is* the channel gain between D-3 and D-2 using RR of cellular. The throughput can be calculated both for cellular users and D2D users using Shannon capacity model $R_c = log_2(1+\gamma_{c1})$ and $R_D = log_2(1+\gamma_D)$. There are many parameters effect on RR allocation of cellular users to D2D users to maintain the quality of service. These parameters are power allocations and interference management of cellular users and D2D users. This is optimization problem to maximize the system throughput by controlling transmission power and interference as presented in Fig. 6. Mathematically this optimization problem can be solved as

$$max_{x_D^c \geq 0, P_D \geq 0} \sum_1^d R_D + \sum_1^c R_c \quad (6)$$

Condition that $R_c \geq R_{c,min}$, $\sum_1^d x_D^c \leq 1$ and $\sum_1^c x_D^c \leq 1$. $R_{c,min}$ *is* the minimum required data rate of the cellular users. From the (4) and (5) it can be observed that D2D users should reuse RR of cellular users of largest gain $\boldsymbol{h_c^d}$. Therefore, D2D users have best SINR. Cellular users should allow D2D users to channel reuse which have smallest gain $\boldsymbol{h_{DB}}$. Therefore, the SINR of the cellular users at the base station is maximized [14]. The distance between D2D users is much smaller than the cellular users and base station practically. Therefore, data rate of D2D users generally much greater than the cellular users. To achieve best data rate, each D2D users should be matched with cellular users using

$$x_D^c = \begin{cases} 1 \; if \; C1 = arg\; max_c \; h_{D2D}^c \\ 0 \; otherwise \end{cases} \quad (7)$$

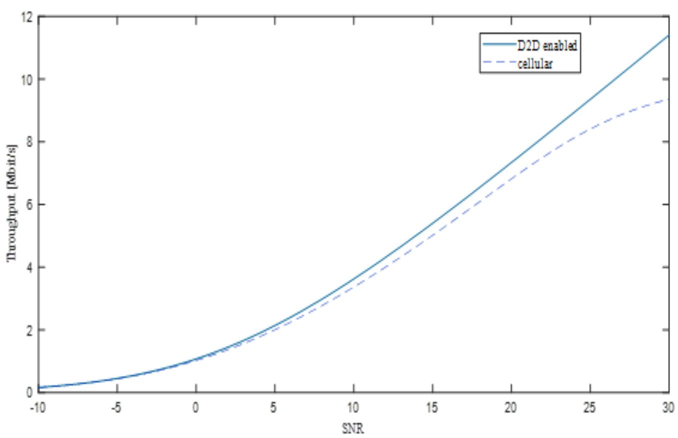

Fig. 6. Network throughput and SNR relation in D2D enabled the cellular system.

This means that D2D users should reuse the RR of cellular users if it has good data rate on that RR. It enhances the system capacity B/Hz as is proofed in Fig. 7. Another important parameter effect on RR allocation is transmitted power of D2D users. Quality of service constraints of cellular users who shares the similar RR with D2D users is not violated. From (4) and (5):

$$R_{c,\ min} \leq log_2(1+\gamma_{c1}) \quad (8)$$

$$R_{c,\ min} \leq log_2\left(1+\frac{P_c h_{C1-B1}}{N_0 + P_D h_{D2B1}}\right) \quad (9)$$

$$P_D \leq \frac{1}{h_{D2B1}}\left(\frac{P_c h_{C1-B1}}{2^{R_{c,\ min-1}}} - N_0\right) = P_{D,\ max} \quad (10)$$

From the above equations quality of service of cellular users is not disrupted as long as D2D users lies in the [0, $P_{D,max}$]. Data rate is also increasing function with power and (6) verify the optimal transmit power of D2D users. As subcarriers increases frequency efficiency increases with visible difference between only cellular users and shared with D2D users as is explained in Fig. 8. D2D RR allocation algorithm follow is described as in Fig. 9.

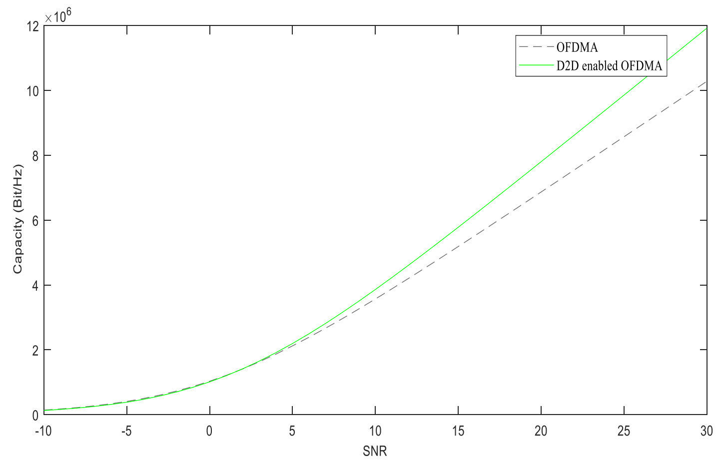

Fig. 7. Show the D2D enabled network capacity is better than simple cellular network due to random radio resources allocation.

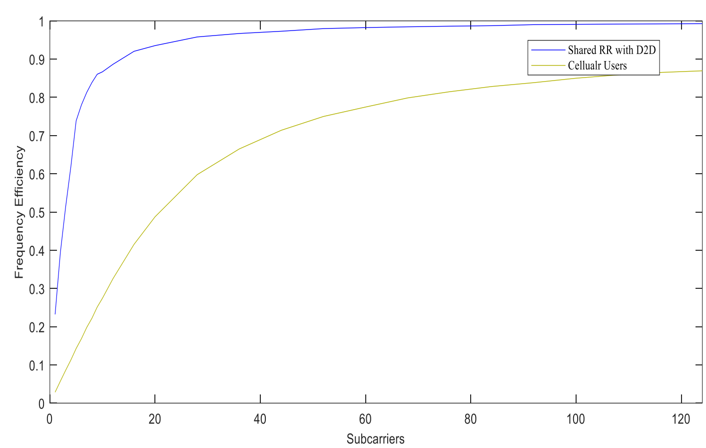

Fig. 8. Explain the efficiency increase with shared radio resources with cellular users and D2D users.

i. Calculate the channel gain of D2D users, cellular users and interference from Figure 1 (*h*c1B1, *h*D2B1, *h*D3D2, *h*c1D3).
ii. Arrange channel gain in one ascending of descending order for comparison.
iii. Start: D2D user=1
iv. While D2D users < total devices
v. Match the RR of cellular users with D2D users using (7)
vi. Measure the D2D users transmit power using (6)
vii. D2D users increment by 1
viii. Cellular users decrement by 1
ix. End
x. End

Fig. 9. Radio resources allocation algorithm flow.

IV. Conclusion and Future Work

After device discovery in D2D communication, resource allocation is the major issue to avoid the interference. In in-band underlay cellular network, swarm-based radio resource allocation technique is proposed which provide the random based resource allocation between cellular users and D2D users. In this proposed model OFDMA network uplink and downlink subchannel are allocated as subcarriers. It enhances the system capacity, frequency efficiency, and throughput. Further, this work can be extended for scheduling between cellular users and D2D users.

Acknowledgment

The authors would like to express their gratitude to the Ministry of Higher Education (MOHE) in Malaysia and Universiti Teknologi Malaysia (UTM) for providing the financial support for this research through the HICOE grant (R. J130000.7823.4F965 4J215). The grant is managed by Research Management Center (RMC) at UTM.

References

[1] O. Hayat, R. Ngah, and Y. Zahedi, "Device discovery for D2D communication in in-band cellular networks using sphere decoder like (SDL) algorithm," (in English), Eurasip Journal on Wireless Communications and Networking, journal article vol. 2018, no. 1, p. 74, Apr 3 2018.

[2] O. Hayat, R. Ngah, and Y. Zahedi, "Cooperative Device-to-Device Discovery Model for Multiuser and OFDMA Network Base Neighbour Discovery in In-Band 5G Cellular Networks," (in English), Wireless Personal Communications, journal article vol. 97, no. 3, pp. 4681-4695, Dec 2017.

[3] G. P. Zhang, K. Yang, and H. H. Chen, "Socially Aware Cluster Formation and Radio Resource Allocation in D2d Networks," (in English), Ieee Wireless Communications, vol. 23, no. 4, pp. 68-73, Aug 2016.

[4] A. Abdelhadi and H. Shajaiah, "Optimal Resource Allocation for Cellular Networks with MATLAB Instructions," arXiv preprint arXiv:1612.07862, 2016.

[5] P. Phunchongharn, E. Hossain, and D. I. Kim, "Resource Allocation for Device-to-Device Communications Underlaying Lte-Advanced Networks," (in English), Ieee Wireless Communications, vol. 20, no. 4, pp. 91-100, Aug 2013.

[6] W. Lin, C. Yu, and X. Zhang, "RAM: Resource allocation in mobility for device-to-device communications," in International Conference on Big Data Computing and Communications, 2015, pp. 491-502: Springer.

[7] G. Wang, L. F. Xiong, and C. Z. Yuan, "Resource Allocation for Device-to-Device Communications Based on Guard Area Underlying Cellular Networks," (in English), Chinese Journal of Electronics, vol. 26, no. 6, pp. 1297-1301, Nov 2017.

[8] A. Asadi, Q. Wang, and V. Mancuso, "A Survey on Device-to-Device Communication in Cellular Networks," (in English), Ieee Communications Surveys and Tutorials, vol. 16, no. 4, pp. 1801-1819, 2014.

[9] M. Dohler, T. Nakamura, A. Osseiran, J. F. Monserrat, and P. Marsch, 5G Mobile and Wireless Communications Technology. Cambridge University Press, 2016.

[10] S. C. Yong, K. Jaekwon, Y. Y. Won, and G. K. Chung, "MIMO-OFDM wireless communications with MATLAB," in Singapore: John Wiley & Sons (Asia) Pte Ltd, 2010, p. 544.

[11] K. J. Zou et al., "Proximity Discovery for Device-to-Device Communications over a Cellular Network," (in English), Ieee Communications Magazine, vol. 52, no. 6, pp. 98-107, Jun 2014.

[12] A. Abdel-Hadi and C. Clancy, "A utility proportional fairness approach for resource allocation in 4G-LTE," in Computing, Networking and Communications (ICNC), 2014 International Conference on, 2014, pp. 1034-1040: IEEE.

[13] D. Astely, E. Dahlman, G. Fodor, S. Parkvall, and J. Sachs, "LTE release 12 and beyond [accepted from open call]," IEEE Communications Magazine, vol. 51, no. 7, pp. 154-160, 2013.

[14] A. Radwan, "Resource Allocation for Device-to-Device Communications Reusing Uplink in Cellular Networks," 멀티미디어학회논문지, vol. 18, no. 12, pp. 1468-1474, 2015.