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Performance Analysis of Resource Allocation Algorithm Based on Simplified Particle Swarm Optimization for Device-to-Device Communication Systems

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Abstract

The development of Device-to-Device (D2D) communication as an alternative communication scheme continues to grow. D2D communication enables each device to communicate directly with other devices without going through the Evolved Node B (eNB). These days, D2D communication can be implemented in conventional cellular communication, and use the same spectrum as the conventional cellular user (underlay). This underlay scheme can improve the cell's spectrum efficiency, but the interference level that happens in the cell is increased. Because D2D communication and cellular communication use the same spectrum, there will be interference between D2D user equipment (DUE) and Cellular user Equipment (CUE). A well-designed radio resource allocation is needed to reduce the interference level, while maintaining the overall performance of the cell. In this research, Simplified Particle Swarm Optimization (SPSO) is proposed to overcome this problem. SPSO is a PSO-based algorithm with a limited number of iterations designed to halt calculations when the PSO algorithm cannot find a solution. If SPSO exceeds the limit iteration, a greedy algorithm is executed to do the allocation process. From the simulation, the SPSO algorithm can achieve 1.3310×10^8 bps, 12.3239 bps/Hz, 2.1328×10^3 bps/Watt and 92% on total sumrate, spectral efficiency, power efficiency, and system fairness respectively. These number is better if compared with the conventional greedy allocation algorithm. The total sumrate, spectral efficiency, and power efficiency are increased by 0.9%, 0.74%, and 0.95% in average datarate, spectral efficiency, and power efficiency respectively. Meanwhile the SPSO's system fairness is decreased by 1.65% compared with the conventional greedy algorithm.

Keywords : D2D Communications; Greedy Algorithm; Radio Resource Allocation, SPSO Algorithm

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1. Introduction

The number of users of cellular communication gradually increases over the time. A massive number of users in one serving cell can cause a heavy traffic load on the Base Station or evolved Node-B (eNB). D2D communication, as a new type of communication that is introduced in fifth-generation (5G) cellular communication technology can be a solution to this problem. DUE, as the user of D2D communication, can communicate directly to the other DUE without using eNB as a hop [1].In an overlay system, communication among DUE uses a predetermined amount of spectrum for communication, distinct from the common CUE that users common cellular type communication, but the overlay system consumes too much spectrum. Meanwhile the underlay scheme, in a cell, DUE and CUE can use the same frequency spectrum [2].

Device-to-device communication is one of the cellular systems used in Orthogonal Frequency Division Multiple Access (OFDMA), which divides the available bandwidth into smaller resources that are allocated to its users. The resources are called resource block (RB). In the underlay system, CUE and DUE use the same limited number of RB. If the DUE and CUE use the same RB at one time, interference occurs on both users [3]. To minimize the effect of interference, a good resource block allocation is needed. The allocation process must consider the sharing impact on each RB if being used by two types of users, which are DUE and CUE. If these users want to use same RB, the interference effect for each type of user must be at minimum level [4]. By applying this condition, the system performances can be increased, especially the spectral efficiency.

There are several previous works related to resource allocation in D2D communication in underlaying networksa. Work [5] shows that proportional based resource allocation algorithm works quite well in D2D underlaying system. The algorithm can improve the system throughput and the system fairness by allocating the RBs proportionally among the users. Work [6] tries to allocate the resource using the principle of graph theory. The algorithm has a better result in sumrate, compared with several conventional allocation algorithms.

Particle Swarm Optimization (PSO)-based RB allocation is proposed. A simplified PSO, thus SPSO, is an allocation algorithm that follows the principles of foraging of a colony [7]. PSO is a popular algorithm that has been used in several works. Work [8] claims that using PSO to allocate the power transmit of each user can increase the throughput of the system. Work [9] also tries to implement the PSO algorithm in user power allocation. Due to the simplicity of the PSO algorithm's structure, it is easy to implement, making it accessible even to beginners in the field of optimization. Additionally, PSO can be used to solve various types of optimization problems, including continuous and discrete problems, multi-objective problems, as well as problems with complex search spaces.

SPSO works like PSO which tries to find the best value using iterative calculation. The calculation follows the basic objective function that is set in the early stage of the calculation. The weakness of PSO is PSO algorithm often converges prematurely and becomes difficult to find a local solution [10]. SPSO addresses this limitation by concluding the iterative calculations after a predefined number of iterations and selecting the best value at that particular stage of the calculation.

To know the performance level of the proposed algorithm, there are several parameters that are being observed. The sumrate represents the total capacity achieved in the system (bit per second), the efficiency of the system represents spectral efficiency which reflects how efficiently the bandwidth is used (notated in bit per second per Hertz (bps/Hz)), and power efficiency which reflects how much capacity that can be achieved in 1 Watt of power (notated in bit per second per Watt ($bps/Watt$)). In terms of equity among users, the fairness parameter is used which reflects the quality gap among users. In this research, the performance of SPSO is analyzed by comparing SPSO with a conventional greedy algorithm.

This paper is written and organized as follows: The first section presents the introduction and the background of this research. The system design is explained in the second section. The third section elaborates on the proposed allocation algorithm used in the research. The fourth section explained about the simulation results and its analysis. The last section which is the fifth section concludes the research.

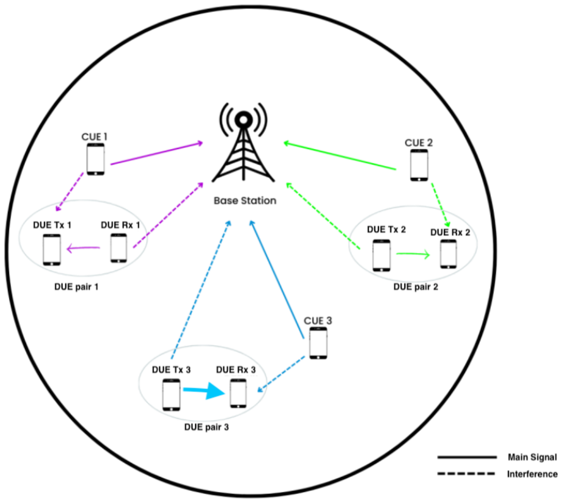

Fig. 1. Model System

2. System Design

2.1. System Model

This research uses a single conventional cellular system with underlying D2D communication in the cell. The multiple access that is being used in the system is OFDMA, which divide the frequency bandwidth into several smaller bandwidth called RBs. These RBs are later allocated to the user to do the communication process. The number of RBs is limited according to the bandwidth system that is being used. The system model can be seen in fig 1. The link that is being observed is uplink communication. In the cell, there are two types of users, CUE and DUE. CUE communicates with Base Station (BS) and DUE Tx communicates with DUE Rx. If these two types of users (CUE and DUE pair) use the same RB (marked by the same color line), the interference happens between these two (the dotted line). The CUE interfered with the DUE Rx, and the DUE Rx interfered with the BS. The cell is assumed to be solitary, with no interference from the adjacent cell.

By using spectrum sharing, the spectral efficiency can be improved to a higher level. This condition is possible if the RB allocation process is well-designed. At first, all the RB is used by each CUE. Then, the DUE searches for the RB that has already been used by CUE to do the communication. In one time interval, one RB can be used by a CUE and a pair of DUE. One CUE and one pair of DUE only can use one RB. To maximize the system performance, the sharing process between CUE and a pair of DUE must not reduce the performance of the system as a whole. The total number of CUEs, DUEs, and RBs is denoted by C, D, and T, respectively, where $C = T$, and $D \leq C$.

2.2. Signal to Interference Noise Ratio (SINR)

SINR is calculated to measure the quality of the main signal and the interference level on each RB. The SINR is calculated on both types of users (CUE and

DUE). At the initial stages, the DUE calculates all the SINR of each RB available to be used. The CUE also measured the SINR of its RB on all DUE pairs that were active in the cell. The output of these processes is the SINR of CUE and the SINR of DUE. SINR on the CUE can be calculated using the Eq. 1 [11]:

$$S^C_{c,d} = \frac{P_C \times \gamma_{c,bs}}{P_D \times \gamma_{dtx,bs} + N_o}, \quad (1)$$

where $S^C_{c,d}$ is the SINR value of c-th CUE if it shares the RB with d-th DUE. P_C, P_D, $\gamma_{c,bs}$, $\gamma_{dtx,bs}$ and N_o are the power transmit of CUE in, power transmit of DUE, the channel gain of CUE-BS link, the channel gain of d-th DUE transmitter to BS link, and the noise power respectively. All calculation is in mWatt.

The SINR value on DUE was also calculated using a similar calculation. The SINR DUE can be calculated using Eq. 2

$$S^D_{c,d} = \frac{P_D \times \gamma_{dtx,drx}}{P_C \times \gamma_{c,drx} + N_o}, \quad (2)$$

where $S^D_{c,d}$ is the SINR value of d-th DUE if it use the same RB as c-th CUE, while $\gamma_{dtx,drx}$, and $\gamma_{c,drx}$ are the channel gain of d-th TX to d-th RX link, and channel gain of c-th CUE to d-th RX link, respectively.

2.3. Datarate and Allocation Matrix

To simplify the allocation process, the datarate matrix must be calculated before the allocation process takes place. The allocation process takes the datarate matrix of each user as input to decide the sharing communication between CUEs and DUEs. The datarate of CUEs and DUEs, noted by $R^C_{c,d}$ and $R^D_{c,d}$ respectively, can be calculated by Eq. 3 and Eq. 4 respectively [12].

$$R^C_{c,d} = B \times log_2(1 + S^C_{c,d}), \quad (3)$$

$$R^D_{c,d} = B \times log_2(1 + S^D_{c,d}), \quad (4)$$

where B is the bandwidth of each RB. The dimension of the datarate matrix is $C \times D$, where each row represents the datarate on each CUE, and each column represents the datarate on each DUE. The formula of datarate CUE and datarate DUE matrix can be seen in Eq. 5 and Eq. 6, respectively.

$$R^C = \begin{bmatrix} R^C_{1,1} & R^C_{1,2} & \cdots & R^C_{1,D} \\ R^C_{2,1} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ R^C_{C,1} & \cdots & \cdots & R^C_{C,D} \end{bmatrix}, \quad (5)$$

$$R^D = \begin{bmatrix} R^D_{1,1} & R^D_{1,2} & \cdots & R^D_{1,D} \\ R^D_{2,1} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ R^D_{C,1} & \cdots & \cdots & R^D_{C,D} \end{bmatrix}. \quad (6)$$

The output of the allocation process is an allocation matrix that represents the sharing process between DUE and CUE, according to Eq. 7.

$$\alpha = \begin{bmatrix} \alpha_{1,1} & \alpha_{1,2} & \cdots & \alpha_{1,D} \\ \alpha_{2,1} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ \alpha_{C,1} & \cdots & \cdots & \alpha_{C,D} \end{bmatrix}, \quad (7)$$

where $\alpha(c,d)$ is 1 if the c-th CUE shares its RB with d-th DUE, otherwise, the value is 0.

2.4. Problem formulation

The main purpose of this work is to analyze the SPSO algorithm. the objective of the allocation algorithm is to maximize the capacity of the system. Maximizing the capacity, means the SINR value of each user is also maximized, and the interference that happens in the system is minimized. The objective of the algorithm is explained in Eq. 8:

$$\max S_R = \sum_{c=1}^{C} \sum_{d=1}^{d} (R^C_{c,d} \times \alpha_{c,d}) + (R^D_{c,d} \times \alpha_{c,d}), \quad (8)$$

Eq. 8 can be achieved by designing the α matrix effectively. Several constraints must be in consideration. These constraints can be seen below :

$$\sum_{c=1}^{C} \alpha_{c,d} = 1; \quad \forall_d \varepsilon D, \quad (9)$$

$$\sum_{c=1}^{C} \sum_{d=1}^{D} \alpha_{c,d} = \begin{cases} C, & \text{if } V \geq C \\ V, & \text{otherwise} \end{cases} \quad (10)$$

Eq. 9 explains that each CUE only shares its RB with one specific DUE pair, and vice versa, while Eq. 10 is to make sure all of the CUE shares its RB to a DUE pair if there are any unallocated DUE pairs.

To solve the problem noted by Eq. 8, the RBs allocation process to DUE must be performed carefully. One pair of DUE can be allocated to one RB that is being used by CUE beforehand after calculating two main constraints. First the RB can maximize the datarate of the current DUE. Second, the allocated DUE on the corresponding RB must not differentiate the datarate of CUE that already used the current RB. This condition can be achieved by calculating the SINR of both user, with the other user as interferrer (CUE is interferred by DUE, and vice versa). The SPSO algorithm is executed to find the solution of the CUE-DUE pair for each RB. In addition, PSO modeling is utilized for finding the best solution within a solution space by simulating the flight activity of a group of particles in that space. The position of these particles in the solution space represents candidate solutions containing optimization variables. This is why the PSO algorithm is employed in problem-solving processes.

2.5. Performance Parameters

To analyze and measure the system performance, several performance parameters are calculated in this study. These parameters are the system's sumrate, spectral efficiency, power efficiency, and fairness level among the users in the system [13]. The sumrate total of the system for all allocated users can be calculated using Eq. 11.

$$S_R = \sum_{c=1}^{C} \sum_{d=1}^{d} (R^C_{c,d} \times \alpha_{c,d}) + (R^D_{c,d} \times \alpha_{c,d}). \quad (11)$$

The spectral and power efficiency of the system, are calculated according to the value of the system's sumrate. The formula for them can be seen in Eq. 12 and Eq. 13 respectively.

$$S_{eff} = \frac{S_R}{B \times R}, \quad (12)$$

$$P_{eff} = \frac{S_R}{(D \times P_D) + (C \times P_C)}. \quad (13)$$

The last parameter that is observed to measure the performance of the allocation algorithm is the fairness level. Fairness level is a degree that describes how fair is the allocation process in the system by calculating the datarate difference on each user. The fairness level is 100% if all users have the same data rate. The fairness level can be calculated using. 14.

$$F = \frac{\left(\sum_{c=1}^{C} \sum_{d=1}^{D} (R^C_{c,d} + R^D_{c,d}) \times \alpha_{c,d}\right)^2}{(C+D) \times \sum_{C=1}^{C} \sum_{d=1}^{D} \left((R^C_{c,d} + R^D_{c,d}) \times \alpha_{c,d}\right)^2}. \quad (14)$$

The motivation for using all these metrics is that this simulation algorithm can be employed to find parameter values that optimize the desired outcomes. For instance, in industry, this algorithm can be used to search for parameter configurations that yield maximum productivity or profit. Additionally, simulation parameter algorithms can assist in making better decisions by providing insights into the impact of parameter changes on the expected outcomes. This enables more informed decision-making.

The proposed algorithm is compared with a traditional greedy-based allocation algorithm to measure the performances [14]. All the performance parameters of the proposed algorithm are compared to the greedy algorithm to know the effect of the proposed algorithm in the system.

2.6. Greedy Algorithm

Greedy algorithm is an allocation algorithm that forms a solution by searching the maximum available value on each iteration. In terms of RB allocation in D2D underlay communication, the greedy algorithm simply searches for the highest total datarate value on each RB. The total datarate ($R^{total}_{c,d}$) calculation on each RB can be seen in Eq. 15.

$$R^{total}_{c,d} = R^C_{c,d} + R^D_{c,d}. \quad (15)$$

The output of allocation process is represented by allocation matrix α and calculated according to Eq. 16

$$\alpha_{c,d} = 1, \quad argmax(R^{total}_{c,d}), \quad (16)$$

which means the $\alpha_{c,d}$ value is 1 if the R^{total} on c-th CUE and d-th DUE is maximum. Due to the cell constraint, each RB only can be used by 1 CUE and 1 DUE in 1 timeslot and 1 specific CUE and DUE can only use 1 RB, after the allocation process c-th CUE and d-th DUE excluded for the following allocation process. The allocation process is repeated until all DUE have 1 RB, or until there are no RB available.

3. Proposed Algorithm

3.1. Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is an iterative algorithm designed to discover the best-fit values for a given problem. The solution is decided using the principle of a bird colony that tries to find the best food spot. The principle is each particle informs the other particles of their best spot fitness values, and the other particles follow the best particle.

The PSO algorithm process begins by initializing the number of particles J where $j = 1,2,3,...,J$. The position of each particle, noted by z^j initially is randomly distributed in a Cartesian field where the x-axis and y-axis represent the c-th CUE and d-th DUE pair respectively. The fitness function for the algorithm is the value of R^{total} on each CUE-DUE sharing pair. The process of this algorithm is iterative in K iteration, where $k = 1,2,3...,K$. This iterative process is executed until the fitness value is the maximum and convergent.

Each iteration examines several values to do the allocation. The values examined on each particle are fit^j_k, fit^j_{best}, z^j_{best} which are the fitness value of j-th particle on k-th iteration, the best fitness value on j-th particle, and the position of j-th particle when the fitness value is on its best, respectively. The process also examines the global best fitness value which is the best fitness value from all the particles, and its position noted by g_{best}, and $gpos_{best}$. The movement of each particle also calculated using 2 types of velocity, which are cognitive velocity (c_{vel}) which represents the individual change rate of velocity for each particle, and social velocity (s_{vel}), which represents the change rate of velocity for the population. The movement and position change of the particle can be calculated by Eq. 17-20.

$$c_{vel} = C_1 \times R_1 \times (z^j_{best} - z^j_k), \quad (17)$$

$$s_{vel} = C_2 \times R_2 \times (gpos_{best} - z^j_k), \quad (18)$$

$$v^j_k = w \times (v^j_{k-1} + c_{vel} + s_{vel}), \quad (19)$$

$$z^j_{k+1} = z^j_k + v^j_k. \quad (20)$$

The C_1 and C_2 are the cognitive and social constants respectively, while R_1 and R_2 are random constants. Notation v^j_k and w are the current velocities of j-th on k-th iteration, and the inertia constant that is being

Algorithm PSO algorithm

initiate g_{best}, and $gpos_{best}$
    (initial value of global best)
for all $j \in J$ **do**
    Initiate $z^{j}_{\square}(x, y)$
        (initiate random particle position)
end for
initiate fit^{j}_{best}, and z^{j}_{best}
    (initial best value of each particle)
for all $k \in K$ **do**
    for all $j \in J$ **do**
        evaluate fit^{j}_{k}
            (evaluate particle fitness value)
        if $fit^{j}_{k} > fit^{j}_{best}$
            update fit^{j}_{best}, and z^{j}_{best}
        end if
            (update particle best value)
        if $fit^{j}_{k} > g_{best}$
            update g_{best}, and $gpos_{best}$
        end if
            (update global best value)
        $c_{vel} = C_1.R_1.(z^{j}_{best} - z^{j}_{k})$
        $s_{vel} = C_2.R_2.(gpos_{best} - z^{j}_{k})$
        $v^{j}_{k} = w.(v^{j}_{k-1} + c_{vel} + s_{vel})$
            (update the particle velocity)
        $z^{j}_{k+1} = z^{j}_{k} + v^{j}_{k}$
            (update the particle position)
    end for
end for
assign $gpos_{best}$ **to** α

Fig. 2. PSO algorithm process

used. After the iteration process is done, the $gpos_{best}$ is defined to allocation matrix α. The process of the PSO algorithm can be seen in Fig. 2.

3.2. Simplified Particle Swarm Optimization (SPSO)

PSO is a powerful algorithm to find a solution to a large-scale problem. But if the solution becomes smaller, the PSO often cannot find the optimal solution. In this research, the RB that has been used by 2 users (CUE and DUE) is excluded from the solution set. This makes the solution set for PSO smaller. The more RBs are allocated, the solution set becomes limited, thus the PSO algorithm cannot find the optimum solution. To overcome this weakness, this research proposes the SPSO algorithm, which is a combination of PSO and greedy algorithm. Usually, in radio resource allocation, the iteration number can be too large, and the convergence of the solution cannot be achieved because the solution matrix becomes smaller (the resources that can be allocated are decreased). This condition makes the PSO allocation algorithm more complex in the later stage of the allocation.

In the early stage of the SPSO allocation process, the PSO allocates the RB to the user. PSO algorithm continues to do the allocation process of RB until PSO cannot find the convergent solution, or the iteration number increases. By limiting the iteration number of PSO. this condition can be avoided. All remaining RB is allocated using a greedy algorithm. By this modification, the calculation time can be reduced to a certain level.

From the initial simulation, resource allocation using PSO algorithm often stuck in finding a solution if the allocation process is in the near-end phase. From Eq. 9, after 1 DUE is allocated to a certain CUE, The RB becomes unavailable, in order to fulfill the constraint. This condition makes the solution set size become smaller. PSO often cannot find the convergent solution in a small size of the problem, and ends up iterating in many times. the SPSO modification limits the number of iterations to solve this problem. So, SPSOs have a constant number of iterations on each allocation process, while PSOs have an increasing number of iterations over time.

Table 1: Simulation Parameter

Parameter	Value
Radius eNB (m)	500 m
Max distance of D2D pair	20 m
Power Transmit CUE	30 dBm
Power Transmit DUE Tx	23 dBm
BW RB (kHz)	180 kHz
BW System (MHz)	12
Number of RB	60
Number of CUE	60
Number of DUE	10,15,20,...,50
Path Loss Models	UMi Path Loss
Channel Models	Rayleigh
TTI	1500

3.3. Simulation Process

This work tries to analyze the performance of the SPSO algorithm by comparing SPSO with the conventional Greedy algorithm. The simulation parameters that are being used in this work can be seen in Table 1.

The simulation process is executed in three stages. The first is the deployment of CUE and DUE in the cell randomly, then each CUE and DUE calculates the SINR of each user on each RB [15]. To simplify the simulation process, 1 CUE is assumed already been allocated to 1 RB, so the allocation process is only used to allocate DUE to RB that is already used by CUE. The second stage is the allocation process, the SPSO algorithm allocates all DUE until all DUE have 1 RB. The last step is performance calculation to measure the performance of the SPSO algorithm. The parameters of SPSO that are being used in this research can be seen in Table 2.

4. Simulation Results and Analysis

To analyze the performance of the proposed algorithm, SPSO is compared with a traditional greedy algorithm. In Fig. 3, the sumrate of the system with variations in D2D users is observed. There are four parameters being observed, which are the sumrate of

Table 2: SPSO Parameters

Parameter	Value
Particle size	10
Iterations	200
Inertia constant (w)	0.8
Cognitive constant (C_1)	2
Social constant (C_2)	2

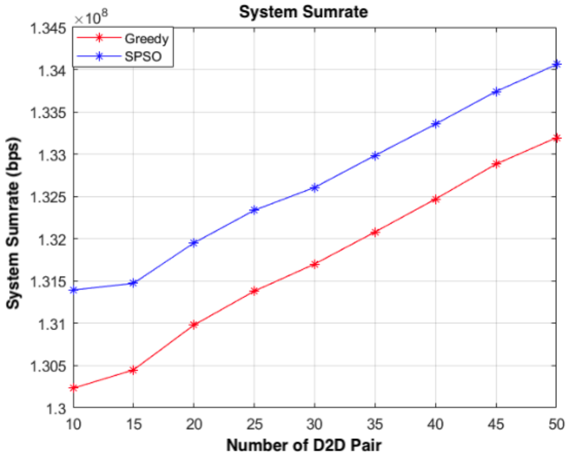

Fig. 3. Sumrate system with variation on D2D user

the system, spectral efficiency, power efficiency, and fairness among users

4.1. System Sumrate and Spectral Efficiency

The simulation result is shown in Fig. 3 and Fig. 4. Fig. 3 shows that the proposed algorithm can achieve a higher system sumrate compared with a greedy algorithm. SPSO can achieve the system sumrate of 1.326×10^8 bps in average ($12.283 bps/Hz$ of spectral efficiency). Compared with the greedy algorithm which achieves 1.317×10^8 in average ($12.195 bps/Hz$ of spectral efficiency) which is 9.5×10^5 lower. This means SPSO can increase the system sumrate and the spectral efficiency up to $0,721\%$. This condition happens because the PSO algorithm on the initial stage of PSO can allocate the RB more optimum by using several iterations to get the best fitness value on sumrate. Although the improvement is not too significant because the greedy also maximizes the sumrate, but the solution set on the greedy algorithm is limited to each RB at a time, while SPSO looks at the solution on all RB at one time. In addition, the SPSO also executes a greedy algorithm to find the solution if the unallocated RB is decreased.

Meanwhile, the increasing number of D2D pairs makes the sumrate also increase. This happens because by sharing its RB, the utility of each RB also increases. This condition also happens because the SPSO and greedy algorithm can allocate the RB sharing effectively, so the interference that happens if the RB is used by 2 users does not give a bad effect on the system.

4.2. Power Efficiency

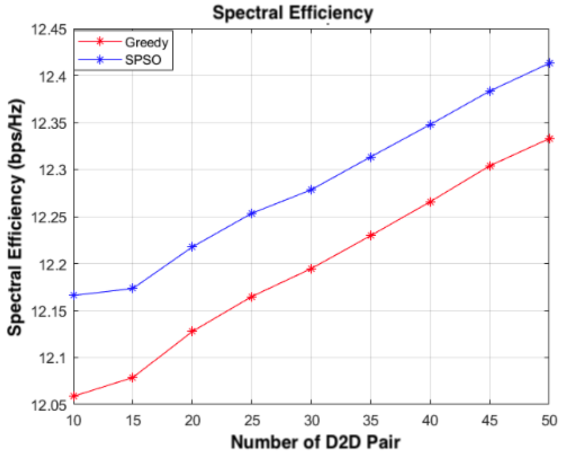

Fig. 4. Spectral efficiency with variation on D2D user

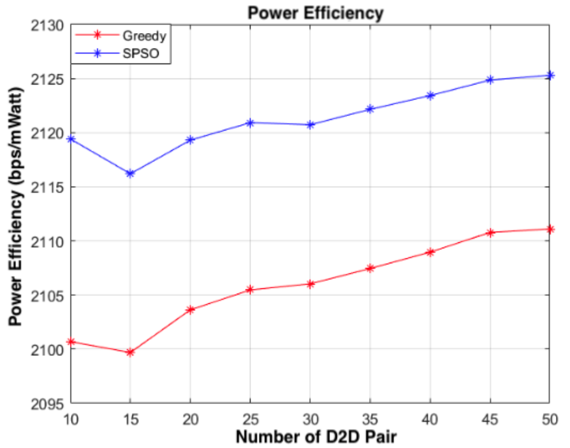

Fig. 5. Power efficiency with variation on D2D user

A similar condition happens to system efficiency. In terms of power efficiency, the SPSO also shows a better value than the greedy algorithm as seen in Fig. 5. The proposed algorithm achieves 2.121×10^3 bps/mWatt on average, which is 15.4 bps/mWatt or $0,731\%$ higher than greedy algorithm whick only achieve 2.106×10^3 bps/mWatt. This also happens because the SPSO search the solution on the bigger set through several iteration, similar with the condition on system sumrate.

4.3. User Fairness

The user fairness defines how much is the sumrate gap that happens among the users. If the sumrate gap among users is small, the fairness index becomes high and vice versa. This works tries to analyzes the fairness from three sides : CUE fairness, DUE fairness, and fairness among all user in the cell or total fairness.

The simulation results for the CUE side can be seen in Fig. 6. On the CUE side, the SPSO achieves the user fairness of 90.12% which is 0.74% lower than greedy that achieve 90.86%. This condition happens because SPSO allocates the best possible RB to the fittest user. This condition makes the other user that being allocated later, only get an average RB, so the gap quality among CUE is bigger than greedy. The increasing number of D2D makes the CUE's fairness is

Table 3: The performance comparison between algorithms

Parameter	Greedy	SPSO	Difference
Data Rate	1.317×10^8	1.3326×10^8	0.721%
Spectral Efficiency	12.2328	12.3239	0.720%
Power Efficiency	2.1125 x 10^3	2.1328 x 10^3	0.731%
Fairness CUE	0.9079	0.9009	−0.74%
Fairness DUE	0.9865	0.9340	−5.55%
Fairness Total	0.9240	0.909	−1.49%

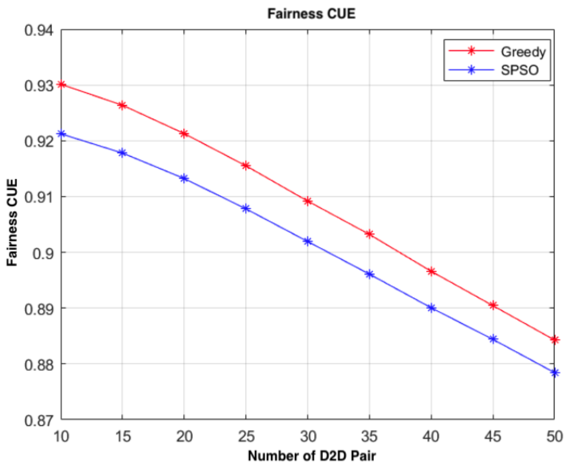

Fig. 6. Fairness CUE with variation on D2D user

decreasing. This condition is caused by the CUE that shared its RB, having lower sumrate compared to CUE that not share its RB. This also creates bigger quality gap among CUE, thus lowering the fairness level.

The fairness result on the DUE side can be seen at Fig. 7. The trend of DUE fairness is constant, that means the fairness of DUE can be maintained even if the number of DUE increases. In DUE fairness, greedy algorithm shows a better result of 98.65% on average. SPSO only achieve 93.30% on average which is 5.55% lower than the greedy algorithm.

Meanwhile, in total fairness, the greedy algorithm has better performance with 92.47% in average total fairness, which is 1.49% higher compared with the SPSO algorithm which only achieved 90.98% total fairness on average. The tendency of SPSO which allocates the fittest RB first, makes the other users that allocated in later stages of the algorithm only can choose RB with lower quality. This condition makes the quality gap among users is increased. The different quality of CUE and DUE also caused the bigger gap in quality among user. In overall, DUE have better sumrate value, because the propagation distance is shorter.

5. Conclusion

The overall performance comparison between Greedy and SPSO algorithm can be seen on Table 3. Overall, SPSO performs better than the greedy algorithm in terms of sumrate, power, and spectral efficiency. The SPSO can increased the system sumrate up to 0.721%, the spectral efficiency by 0.720%, and power efficiency

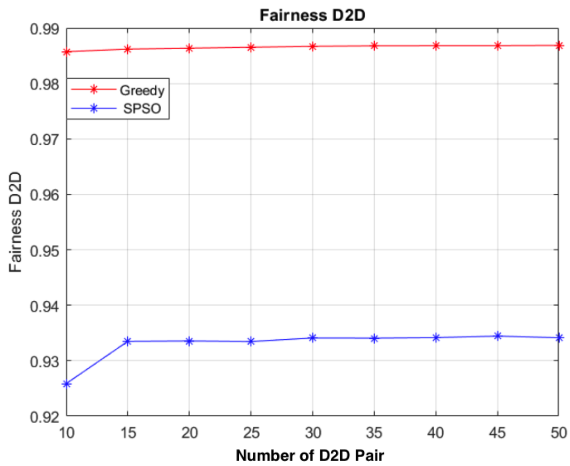

Fig. 7. Fairness DUE with variation on D2D user

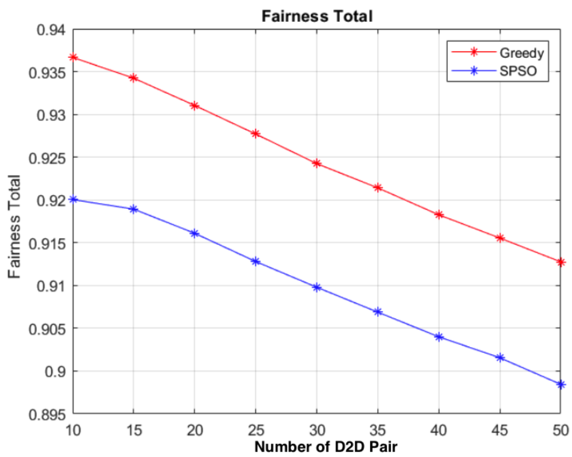

Fig. 8. Fairness System with variation on D2D user

by 0.731%. This happens because SPSO allocates the best RB to the optimal user, allowing the RB with the best quality to be used optimally by specific users, SUE and DUE. However, in contrast, SPSO cannot maintain system fairness as well as the greedy algorithm. SPSO system fairness decreased by 0.74% on CUE side, DUE fairness is decreased by 5.55%, and total fairness is decreased by 1.49%. This happens because by allocating the RB to best users, the quality gap among users is also increased, that makes the fairness is decreased.

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