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Greedy Based Radio Resource Allocation Algorithm with Sectoring Scheme in D2D Underlaying Communication

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Abstract
D2D communication is a communication that allows users to communicate without passing through the Base Station (BS). The D2D Underlaying communication system can use the same Resource Block (RB) as the Cellular User Equipment (CUE). Implementing this communication system can ease the burden on BS and can transmit data with higher throughput in low power. However, using RB simultaneously can cause interference and therefore an RB allocation scheme is needed. The algorithm used in the scheduling process of the uplink RB owned by CUE to the D2D pair is the joint greedy algorithm with sectoring scheme. This work used a scenario where the value of the D2D pair are varied. The parameters measured in this simulation were sum-rate, spectral efficiency and fairness. The simulation results show that the joint greedy with sectoring allocation scheme has good energy efficiency and spectral efficiency values of 6.063×10^6 bps/watt and 16.982 bps/Hz. On the other hand, the D2D fairness value in the joint greedy with sectoring allocation scheme is 0.886.

Keywords: Joint Greedy; Greedy; Sectoring; Resource Block; Device to Device

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1 Introduction

The needs of the current society have been increasing and are not only limited to foods, clothes or houses. Human needs have evolved along with the rapid development of technology, which has resulted in the need for adequate communication technology. As the effect, the number of mobile broadband traffic in recent decades has also been increasing quite rapidly. When it is not managed properly, it will result in service degradation. One way to solve this problem is by implementing a Device to Device (D2D) communication system underlaying the Long Term Evolution-Advanced (LTE-A) communication network [1].

D2D communication allows Cellular User Equipment (CUE) to communicate without going through the Base Station (BS). D2D communication works by using the same Resource Block (RB) as CUE. There are two advantages of D2D communication. First, it can transmit data with higher throughput in lower power due to shorter distances. Second, BS can ease its own burden and can serve more users as it allows the spectrum to be reused [2]. On the other hand, the use of RB together in D2D communication causes interference, so it is necessary to allocate RB properly to minimize the interference value [3].

In [4] the formulation of joint mode selection, scheduling, and power control was carried out. In addition, a distributed suboptimal joint mode selection and resource allocation scheme were proposed. The work found that the distributed scheme performs close to the optimal scheme both in terms of resource efficiency and user fairness. In [5] a new resource allocation scheme (joint resource block scheduling and power control) was carried out for D2D communication on the LTE-Advanced network. The aim was to maximize spectrum utilization by finding the minimum transmission length in terms of time slots for D2D links while protecting the cellular users from harmful interference and guaranteeing the QoS of D2D links. The results showed that the simulation scheme can improve spectrum utilization. Although the overall transmission power is increased, the proposed scheme

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can significantly reduce the transmission length. In [6] a novel two-layer approach was carried out which allows to find the optimum at each iteration by decoupling the EE optimization problem of joint resource allocation and power control into two separate steps. The results showed an increase in Energy Efficiency by using the proposed iterative resource allocation and power control scheme. In [7] proposed power control scheme and user grouping method to keep the rational energy consumption level of the resource management scheme. The result showed the user grouping method is a solution for Carrier Aggregation (CA) scheme that prevents edge cell user get the resources from the high-frequency carrier. The power control scheme and user grouping method can optimize the spectral and energy efficiency without increasing the time complexity of the system. In [8] proposed joint-greedy algorithm and greedy based allocation algorithm to find the best resource for each D2D user. From the simulation results showed that the proposed algorith can improve spectral efficiency and energy efficiency, and maintain the fairness among D2D pair.

This paper discusses the allocation of RB using the joint greedy with sectoring algorithm in the uplink direction. The results obtained were compared with three other schemes, namely the Greedy algorithm, the Greedy algorithm with a sectoring scheme, and the Joint Greedy algorithm. The simulation system in this work used a scenario where the value of the D2D pairs varies.

2 Experimental Method

This work combined the sectoring schemes in the Greedy and Joint Greedy algorithms. First, users (CUE and D2D pair) were randomly placed in two dimensions and SINR calculations were performed for each user. Second, each user was grouped into four groups and paired according to the provisions of the sectoring scheme. After that, resources were allocated and performance parameters were analyzed. The results were compared with an algorithm without a sectoring scheme. The proposed block diagram can be seen in Figure 1.

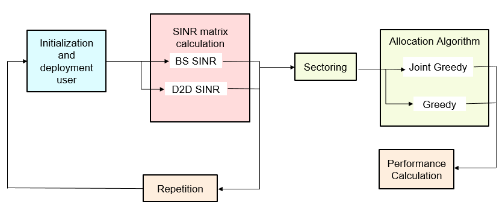

Fig. 1. Block Diagram.

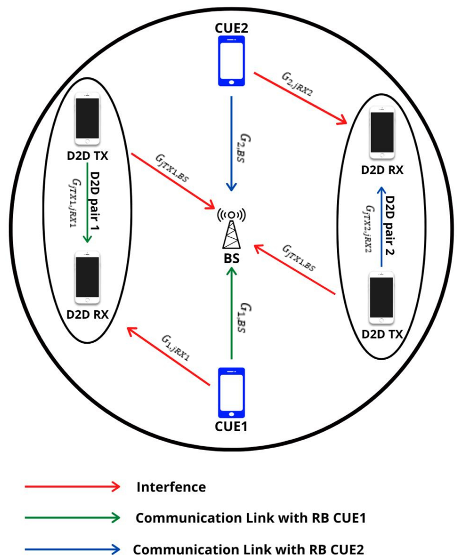

Fig. 2. System Model.

2.1 *System Model*

The system model used in this work was a single cell consisting of CUE, BS, and D2D pairs (Tx and Rx) which randomly placed in two dimensions. In this work, one CUE can only be associated with a pair of D2D so that the number of CUEs must be the same or more than the number of D2D pairs. The communication direction used in this work was the uplink direction, where the signal moves from the CUE to the BS. The system model used is illustrated in Figure 2.

Pathloss is the loss or weakening of information signal power when passing through the air during the signal transmission process. The path loss value can be calculated using the following equation [9].

$$PL_{i,j} = 36.7\log_{10}(d) + 22.7 + 26\log_{10}(fc) \quad (1)$$

where d is the distance between sender and receiver in meters (m) and f_c is the carrier frequency in Gigahertz (GHz).

To find the gain of a channel, it can be calculated using the following equation [10].

$$G_{i,j} = PL_{i,j} + X_\sigma + \Pi \quad (2)$$

The $PL_{i,j}$ is the path loss value described in equation 1, X_σ is the random variable for Lognormal shadowing, and Π is the random variable for Rayleigh fading.

Signal to Noise and Interference Ratio (SINR) is a comparison of the main signal with the interference and noise values that arise. SINR calculation is carried out from the BS side symbolized by $\gamma_{i,j}$ and the D2D side symbolized by $\beta_{i,j}$.The SINR value can be calculated using the following equation [11].

$$\gamma_{i,j} = \frac{P_i \cdot G_{i,BS}}{No + P_j \cdot G_{jTX,BS}} \tag{3}$$

$$\beta_{i,j} = \frac{P_j \cdot G_{jTX,jRX}}{No + P_i \cdot G_{i,jRX}} \tag{4}$$

$G_{i,BS}$in the equation is the channel gain between CUE and BS, $G_{jTX,BS}$ is the channel gain between D2D TX devices with BS, $G_{jTX,jRX}$ is the channel gain between D2D TX and D2D RX, $G_{i,jRX}$ is the channel gain between CUE devices and D2D RX, while P_i and P_j respectively, are CUE and D2D TX transmission powers.

2.2 Simulation Process

This work will compare the joint greedy with sectoring algorithm with three other schemes, namely the Greedy algorithm, the Greedy algorithm with a sectoring scheme, and the Joint Greedy algorithm. The capacity value of each user received by BS. This capacity value will be the input for the algorithm. The output produced after implementing the allocation scheme is an allocation matrix with new variable ($X_{i,j}$). $X_{i,j} = 1$ if CUE (i) using the same RB with D2D pair (j) and $X_{i,j} = 0$ if CUE (i) using different RB with D2D pair (j).

2.2.1 Greedy Algorithm

The process of allocating RB using the greedy algorithm is done by looking at the maximum value of the CUE capacity and the D2D pair. The maximum value taken is the value that comes first. The RB which has been allocated to a D2D pair cannot be used by any other D2D pair. The proposed greedy algorithm flowchart can be seen in Figure 3. Greedy algorithm requires one input that is total SINR capacity. This total capacity is obtained from the sum of $\gamma_{i,j}$ and $\beta_{i,j}$.

2.2.2 Joint Greedy Algorithm

The process of allocating RB using the joint greedy algorithm is divided into two stages. The first stage is to find the maximum value of the BS capacity. This maximum score will be a candidate in the second stage. In the second stage, the value of D2D capacity taken is based on the results of the first stage. The values taken from these two stages will be allocated to one D2D pair. The RB which has been allocated to the D2D pair cannot be used on any other D2D pairs.The proposed joint greedy algorithm flowchart can be seen in Figure 4. The joint greedy algorithm requires two inputs namely sinr capacity $\gamma_{i,j}$ and SINR capacity $\beta_{i,j}$.

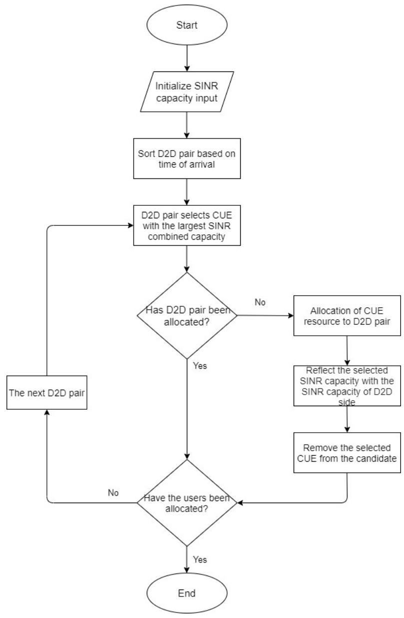

Fig. 3. Greedy algorithm flowchart.

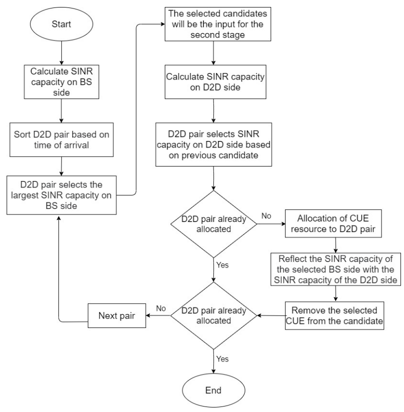

Fig. 4. Joint greedy algorithm flowchart.

2.2.3 Sectoring Scheme

The sectoring scheme is carried out by grouping a cell into four parts, which are Groups 1, 2, 3 and 4. Each D2D pair can only use RB from CUE which is not adjacent. This aims to minimize the interference value. Group 1 pairs with group 3 while group 2 pairs with group 4. This means that each D2D pair can only use RB from their partner's CUE. The application of sectoring scheme can minimize the interference. This is because D2D users will use CUE's RB which is located far from the D2D. The farther the distance between D2D and CUE, the interference value will be reduced. In Figure 5, it can be seen that group 3 D2D uses RB from group 1s CUE.

2.3 Simulation Parameter

This work examined the performance of the Greedy and Joint Greedy algorithms, which were compared

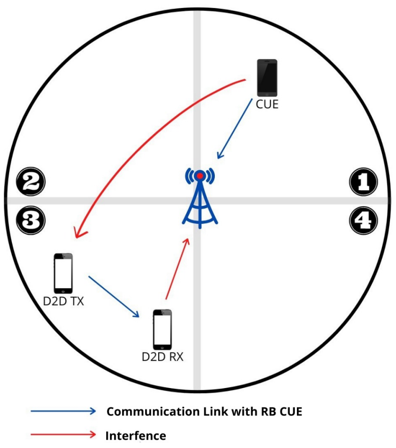

Fig. 5. Sectoring Scheme

using a sectoring scheme. Testing was conducted on a computer with the assistance of a simulation software. These simulation parameters is based on the parameters in previews research [8]. Time Transmission Interval (TTI) used in this simulation is 1000, that means the program is looping by 1000 times. The test parameters used are described in Table 1.

Table 1: Parameter Simulasi

Parameters	**Value**
Cell Radius	500 m
D2D Radius	40 m
Number of CUE	50
Number of D2D Pair	10, 20, 30, 40, 50
CUE Transmit Power	0.5 watt
D2D Transmit Power	0.1 watt
Resource Block	50
Frequency	1800 MHz
Pathloss Model	UMi pathloss
Bandwidth RB	180 kHz
Time Transmission Interval	1000
Channel Model	Rayleigh (1,1)
Shadowing Model	Lognormal (0,1)

The parameters analyzed in this work were energy efficiency, spectral efficiency, and D2D fairness. All these parameters were analyzed and their tendency towards the number of variations in the D2D pairs was observed.

Energy efficiency refers to the energy efficiency of transmitting a number of bits. The greater the energy efficiency value is, the lower the power used in sending data. In this work, the test on the energy efficiency of the system when the i-th CUE device distributes resources to the j-th D2D pair was calculated using the following equation [12].

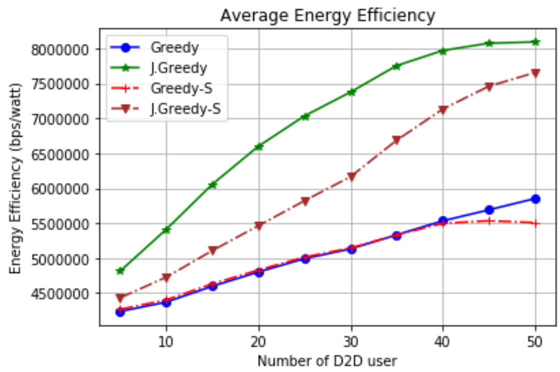

Fig. 6. Energy Efficiency

$$EE = \frac{\sum_{i=1}^{C}\sum_{j=1}^{D}\mu_{i,j}}{C\cdot\sum_{i=1}^{C}P_C + D\cdot\sum_{j=1}^{D}P_D} \tag{5}$$

In the equation, C is the number of CUE devices and D is the number of D2D pairs.

Spectral efficiency describes the number of bits that can be carried at a given frequency. A system will be more efficient if it has a high spectral efficiency value. The spectral efficiency value can be calculated using the following equation [13].

$$SE = \frac{\sum_{i=1}^{C}\sum_{j=1}^{D}\mu_{i,j}}{RB.B} \tag{6}$$

The RB is the number of resource blocks in the system.

Fairness is a fairness value calculated based on the throughput received by each UE. The amount of fairness value can be calculated using the following equation [14].

$$Fairness = \frac{(\sum\mu_{i,j})^2}{n.\sum\mu_{i,j^2}} \tag{7}$$

The n in the equation is the number of D2D devices in the system.

3 Results and Discussion

3.1 *Energy Efficiency*

From the simulations performed, the addition of the number of D2D pairs gave a positive tendency. The data rate comparison graph in each scheme is shown in Figure 6, while the details of the energy efficiency amount can be seen in Table 2.

Based on Table 2, the value of the energy efficiency of the joint greedy with sectoring algorithm occupies the second rank. The sectoring scheme causes fewer resource options for D2D communication, thus allowing the preferred user to have a poor SINR value. The first rank is occupied by the Joint Greedy algorithm. The Joint Greedy with sectoring algorithm has an energy efficiency value of 6.063×10^6 bps/watt.

Table 2: Energy Efficiency

Allocation Scheme	**Energy Efficiency (bps/watt)**
Joint Greedy	6.917×10^6
Join Greedy with Sectoring	6.063×10^6
Greedy	5.053×10^6
Greedy with Sectoring	5.016×10^6

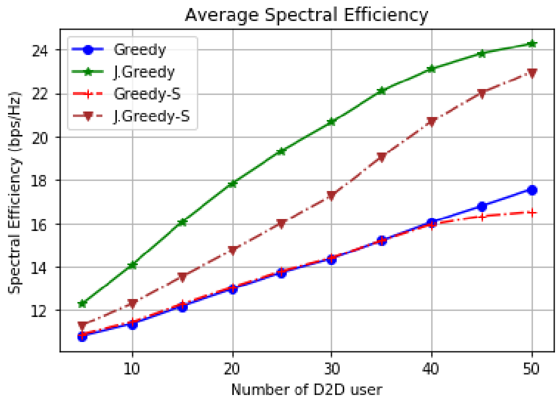

Fig. 7. Spectral Efficiency

This value is almost the same as Joint Greedy algorithm with decrease only 8.54×10^5, increase 1.01×10^6 than Greedy with sectoring algorithm, and increase 1.05×10^6 than Greedy algorithm. The comparison of the value of energy efficiency can be seen in Table 5.

3.2 Spectral Efficiency

From the simulations performed, increasing the number of D2D pairs gives a positive tendency towards the spectral efficiency value. The amount of spectral efficiency value depends on the sum-rate. The spectral efficiency comparison graph in each scheme is shown in Figure 7, while the details of the spectral efficiency magnitudes is in Table 3.

Table 3: Spectral Efficiency

Allocation Scheme	**Spectral Efficiency (bps/Hz)**
Joint Greedy	19.349
Joint Greedy with Sectoring	16.982
Greedy	14.101
Greedy with Sectoring	13.982

Based on Table 3, the value of the spectral efficiency of the joint greedy with sectoring algorithm ranks second. The sectoring scheme causes fewer resource options for D2D communication, thus allowing the preferred user to have a poor SINR value. The first rank is occupied by the Joint Greedy algorithm. The Joint Greedy with sectoring algorithm has a spectral efficiency value of 16.982 bps/Hz. This value is almost the same as other allocation schemes with decrease only 2.367 bps/Hz than Joint Greedy algorithm, increase 2.881 bps/Hz than Greedy with sectoring algorithm, and increase 3 bps/Hz than Greedy algorithm. The comparison of the value of energy efficiency can be seen in Table 5.

3.3 Fairness D2D

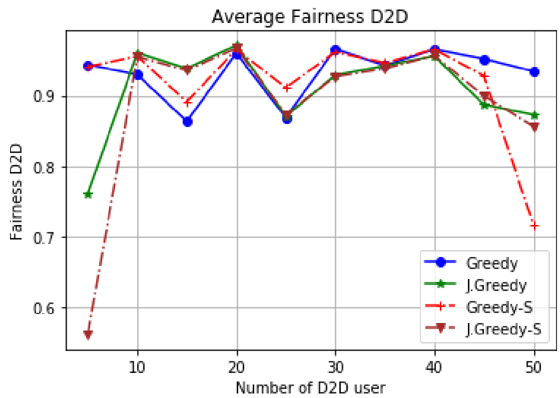

Fig. 8. Fairness D2D

From the simulation, the increase in the number of D2D pairs tends to decrease the fairness value on the D2D side. The amount of fairness value on D2D depends on the amount of the sum-rate and the number of D2D pairs. The data rate comparison chart in each scheme is shown in Figure 8, while the details of the D2D fairness can be seen in Table 4.

Table 4: Fairness D2D

Allocation Scheme	**Fairness D2D**
Greedy	0.932
Greedy with Sectoring	0.918
Joint Greedy	0.908
Joint Greedy with Sectoring	0.886

Based on Table 4, the fairness value of the Joint Greedy with sectoring algorithm is in the last rank.This happens because allocation resource in Greedy algorithm is allocated based on combination between the largest capacity of BS and the D2D pair. Meanwhile allocation resource in Joint Greedy algorithm is allocated based on the largest capacity of BS, than the largest capacity of D2D. The Joint Greedy with sectoring algorithm has a fairness value of 0.886.This value is almost the same as other allocation schemes with decrease only 0.022 than Joint Greedy algorithm, decrease 0.046 than Greedy with sectoring algorithm, and increase 0.032 than Greedy algorithm. The comparison of the value of energy efficiency can be seen

Table 5: Comparison of Performance Parameters

Algorithm	Energy Efficiency (bps/watt)	Spectral Efficiency (bps/Hz)	D2D Fairness Index
J.Greedy-S	6.063x10ˆ6	16.982	0.886
J.Greedy	+(8.54x10ˆ5)	+(2.367)	+(0.0220
Greedy-S	-(1.01x10ˆ6)	-(2.8810	+(0.046)
Greedy	-(1.05x10ˆ6)	-(3)	+(0.0320

in Table 5.

4 Conclusion

This work investigated the energy efficiency, spectral efficiency, and fairness values of D2D in the joint greedy with sectoring algorithm. The results of the joint greedy with sectoring algorithm were compared with other allocation schemes, which were joint greedy, greedy, and greedy with sectoring. The main objective of this work was to analyze the system performance. From the simulation results, the joint greedy with sectoring allocation scheme has good energy efficiency and spectral efficiency of 6.063×10^6 bps/watt and 16.982 bps/Hz. However, the D2D fairness value in the joint greedy with sectoring allocation scheme is 0.886.

From this work, it can be concluded that the sectoring scheme with the joint greedy algorithm is not the best solution to minimize the interference value in the underlaying D2D communication. The sectoring scheme causes fewer resource options for D2D communication, thus allowing the preferred user to have a poor SINR value. In addition, the implementation of a sectoring scheme will cause the increased of complexity, thus the simulation process is longer. On the other hand, the discussion of sectoring schemes in this study is not too deep.

References

[1] Doppler, Klaus, et al. "Device-to-device communication as an underlay to LTE-advanced networks." IEEE communications magazine 47.12 (2009): 42-49.

[2] Huang, Bo-Yuan, et al. "Resource allocation in D2D communication-A game theoretic approach." 2014 IEEE International Conference on Communications Workshops (ICC). IEEE, 2014.

[3] Chung, Jihoon, Donggun Kim, and Youngchul Sung. "Design of amplify-and-forward helper stations for cellular networks with device-to-device links." The Journal of Korean Institute of Communications and Information Sciences 41.5 (2016): 539-545.

[4] Belleschi, Marco, Gabor Fodor, and Andrea Abrardo. "Performance analysis of a distributed resource allocation scheme for D2D communications." 2011 ieee globecom workshops (gc wkshps). IEEE, 2011.

[5] Phunchongharn, Phond, Ekram Hossain, and Dong In Kim. "Resource allocation for device-to-device communications underlaying LTE-advanced networks." IEEE Wireless Communications 20.4 (2013): 91-100.

[6] Jiang, Yanxiang, et al. "Energy-efficient joint resource allocation and power control for D2D communications." IEEE Transactions on Vehicular Technology 65.8 (2015): 6119-6127.

[7] Prabowo, Vinsensius Sigit Widhi, et al. "Energy efficient resources allocations for wireless communication systems." Telkomnika 17.4 (2019): 1625-1634.

[8] Prabowo, V. S. W., et al. "Joint-Greedy Allocation Algorithm on D2D Communication Underlaying Networks." 2019 IEEE Asia Pacific Conference on Wireless and Mobile (APWiMob). IEEE, 2019.

[9] Sousa, Sofia, Fernando J. Velez, and Jon M. Peha. "Impact of propagation model on capacity in small-cell networks." 2017 International Symposium on Performance Evaluation of Computer and Telecommunication Systems (SPECTS). IEEE, 2017.

[10] Khan, Muhidul Islam, et al. "Cooperative reinforcement learning for adaptive power allocation in device-to-device communication." 2018 IEEE 4th World Forum on Internet of Things (WF-IoT). IEEE, 2018.

[11] Song, Xin, et al. "Joint uplink and downlink resource allocation for D2D communications system." Future Internet 11.1 (2019): 12.

[12] Xu, Hao, et al. "Energy-efficient resource allocation in D2D underlaid cellular uplinks." IEEE Communications Letters 21.3 (2016): 560-563.

[13] Prabowo, Vinsensius Sigit Widhi, et al. "Energy efficient resources allocations for wireless communication systems." Telkomnika 17.4 (2019): 1625-1634.

[14] Jain, Rajendra K., Dah-Ming W. Chiu, and William R. Hawe. "A quantitative measure of fairness and discrimination." Eastern Research Laboratory, Digital Equipment Corporation, Hudson, MA (1984).

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