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Modified of Mixed Strategy Algorithm for Power Allocation on D2D Underlay Communication

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Abstract: As time passes by, the need for telecommunication services will increase along with increasement of human's population. To anticipate the flooding requests of telecommunication services, one of the solutions offered is by implementing D2D communication, especially in 5G architecture. In D2D 5G, focusing on underlay communication D2D uses the same frequency spectrum, so that opportunity of interference may happen, but the value of spectral efficiency (SE) may increase as a result of the effectiveness of the spectral that occurs. In terms of financing and its development, underlay D2D communication is considered more profitable for service providers. Based on this point, the authors propose a novel algorithm of modified mixed strategy algorithm for power allocation to make the power transmission cost be more effective in terms of total power used for transmitting data and power efficiency. After the experiment conducted, the result shows that modified mixed strategy outperform baseline model which uses no power allocation algorithm by having a power efficiency 5x bigger compared to based model and also for the total power used, the proposed mixed strategy algorithm has up to 57.86% lesser total power used compared to baseline model.

Keywords: keyword 1; 5G 2; D2D 3; Underlay communication 4; Mixed strategy algorithm 5; Power allocation.

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1. Introduction

As time passes by, human needs for the use of telecommunications technology is increasing. The growth of users of telecommunication services can be seen in data from the Indonesian Internet Service Providers Association (APJII). Based on the results of a survey conducted by this institution, there was an increase in internet users by 73.7% from 2019 to 2020, based on surveyed data, almost 266.9 million people in Indonesia use telecommunications technology services and this is predicted to continue to increase [1]. The problem between limited network bandwidth and the need for increasing resources is a challenge in increasing the capacity of a cellular network in a base station (BS).

One kind of way to overcome traffic congestion that occurs in BS is to implement Device to Device (D2D) communication system. D2D communication is communication that allows between mobile devices to communicate in a direct way without going through BS or evolved Node B (eNB) [2][3]. The advantages of using D2D communication in addition to being able to carry out data exchange without going through eNB are that it has low latency, increases the value of throughput, and reduces power usage in the delivery process data due to the characteristics of D2D communication that is able to provide access to users to carry out direct link communication if they are in an adjacent position [4]. D2D communication can work on both the outband and inband spectrum. In inband spectrum allocation schemes, D2D communication can take place in overlays or underlays. In D2D overlay communication, there is no overlapping of the frequencies used, so this technique focuses on utilizing existing resources so that it is expected that no resources are wasted, on the other hand, the D2D underlay uses the same frequency spectrum, so that opportunities the occurrence of interference may happen, but the value of spectral efficiency (SE) may increase as a result of the effectiveness of the spectral that occurs. In terms of financing and its development, underlay D2D communication is considered more profitable for service providers [5].

Related studies on the use of underlay D2D communication have been carried out to minimize the effects of interference that occur as a result of the use of the same RB. In the study [6], Yucheng Wu et al conducted a trial to improve energy efficiency in D2D communication by separating power control and channel allocation into sub-problems to be solved. For power control problems, the category based on the Lambert W function is used to improve energy efficiency in the D2D pair, while for the channel allocation problem, the Gale-Shapley algorithm is used to generate channel preferences that can be used for increasing the signal to interference plus noise ratio (SINR) in mobile users and energy efficiency in the D2D pair, the results obtained that the algorithm used succeeded in improving energy efficiency and improving the quality of transmission rate. Other research [7], utilizing deep learning model reinforcement learning, this model works through trial and error to be able to produce optimal decisions in the context of D2D communication in order to improve power allocation, while still maintaining good quality. The results of this study successfully showed that the non-cooperative deep learning reinforcement algorithm method can improve performance in real-time scenarios and provide optimal QoS values. Another study [8] promoted the benefits of heuristic-based greedy and mean greedy algorithms for allocating RB in D2D communication which aims to improve system data rates. The use of these two heuristic-based algorithms has succeeded in increasing the overall system data rate.

Different from previous studies, the authors take an initiative to utilize the game theory mixed strategy algorithm on the power allocation used, combined with the greedy algorithm for the allocation of resource blocks in underlay D2D communication. The results of the designed simulation will then be compared with underlay D2D communication which only uses algorithm greedy for allocating the resource blocks used.

2. Materials and Methods

2.1 Greedy Algorithm

Greedy algorithm is an algorithm that is generally used to perform scheduling by allocating RB by selecting the maximum channel quality condition, so that the user will get the best channel. Once the RB is properly allocated to the user, the RB that has been used cannot be reused for the next user, this process occurs iteratively until all D2D pairs obtain the mobile user resource [9].

2.2 Mixed Strategy Approach

Mixed strategy is one part of game theory that allows mobile devices to not only choose one action to be performed, but can choose several actions depending on the circumstances, per- lift forms a probability of the action to be performed to achieve a condition called the Nash Equilibrium Point [7]. In its implementation, the mix strategy algorithm is an algorithm that can be used for power allocation in an underlay uplink communication scheme that allows the device to use optimal power according to the needs of the user, the process of obtaining calculations from optimal power usage is called the term Nash Equilibrium Point [10]. This condition plays a role in making power usage decisions in CUE communication and D2D pairs.

2.3 Proposed Model

The scenario proposed is by variating the number of D2D pairs starting from 10 to 20 pairs of D2D pairs within a cell radius of 500 m. Each CUE can only share one of the same RB with a D2D pair. The study begins with the initialization of the pair of D2D and CUE, then spread randomly. After the user spread is carried out, then SINR calculations are carried out on BS and on D2D recipients. For RB allocation, allocation is done using an iterative greedy algorithm so that all D2D pairs are allocated. After greedy algorithm successfully deployed, the next step is by allocating power for transmitting data, but before that, there are three schemes in the resource allocation that is implemented, first, the maximum capacity value is obtained from summing the total capacity of the CUE and the D2D pair then allocated using a greedy algorithm to process it as input for power allocation.

Table 1. Proposed scheme parameter

Parameter	Value
Radius Cell	500m
Radius D2D	50m
D2D Pairs	10:20:1
Total CUE	20
Transmit Power CUE	0,2 W
Transmit Power D2D	0,1 W
Noise Energy Thermal	10^{-7} W
Transmit Frequency	2,3 GHz
Bandwidth Channel	5 MHz
Model Pathloss	*log distance model pathloss*
Pathloss exponent value	3

The second variation is done by calculating the allocation of resources using the total capacity of the CUE, then the results are projected to the total results of the D2D pairs, so that they become different inputs for the next process and the last one by utilizing the total capacity of the D2D pairs which are then processed for resource allocation, after obtaining the results, then projected at the total capacity of the CUE, so the authors have three inputs for the next process. Once the RB is allocated, the result will be an input for the modified mixed strategy algorithm. The modified mix strategy algorithm has a power value range of 20-200 mw per pair, so in its realization, this algorithm will help in allocating the most efficient power that can be used to transmit data. The results obtained are then tested with performance parameters and compared with conditions before using the mixed strategy algorithm. The parameters of the proposed scenario can be seen in Table 1.

2.4 Performance Parameters

2.4.1 Sum Data Rate

Sum data rate is total data rate that is given by adding data rate on both of CUE of this D2D communication, they are D2D pairs and CUE. Sum data rate having impact on other performance parameters, thus sum data rate value must be the best value possible in order giving any best for this simulation. Sum data rate is given by:

$$SR = \sum_{i=1}^{N}\sum_{j=1}^{M}(x_{i,j}\,\mu C_{i,j}) + (x_{i,j}\mu D_{i,j}) \tag{1}$$

2.4.2 Power Efficiency

Power efficiency is a data rate value that is sent divided by total power (bps/mWatt). Power efficiency shows how efficient power that is used. Power efficiency formula can be seen in:

$$PE_{i,j} = \frac{SR}{P_C + P_D} \tag{2}$$

SR is sum data rate value, P_C is transmitted power from CUE and P_D is transmit power from D2D.

2.4.3 Spectral Efficiency

Spectral efficiency (SE) is performance parameters which use to know the use of resource blocks (RB) allocation [11]. Spectral efficiency shows how many bits are transmitted every second toward bandwidth that is given (bps/Hz). SE equation can be seen in:

$$SE_{i,j} = \sum_{i=1}^{C}\log_2\left(1 + \frac{p_c^k\, g_c^k}{\sum_{i=1,j\neq i}^{N}\gamma_{j,c}\, p_j^c\, g_j^c + N_0}\right) \tag{3}$$

$$SE_{i,j} = \frac{SR}{rb \cdot B} \tag{4}$$

2.4.4 Total Power Used

Total power used is a performance parameter that is used for evaluating the power used when transmitting information which transmitted in form of Watt/mWatt. The equation of total power used can be seen in:

$$TE_{i,j} = P_C \cdot N + P_D \cdot M \tag{5}$$

P_C is transmit power of CUE times by N, which is total of CUE used and P_D is transmit power D2D times by M which is total of D2D pairs.

3. Results

This section will show about the result of proposed work compared to traditional method in form of graphic information for every result of performance parameters that being tested.

3.1. Sum Data Rate Result

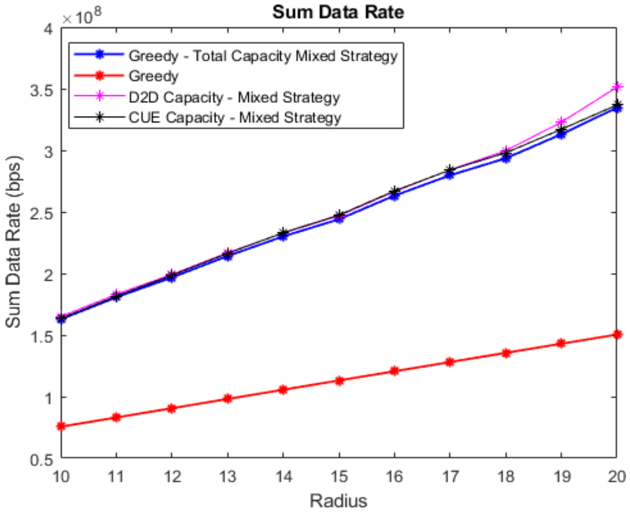

Figure 1. Sum Data Rate Result

3.2. Power Efficiency Result

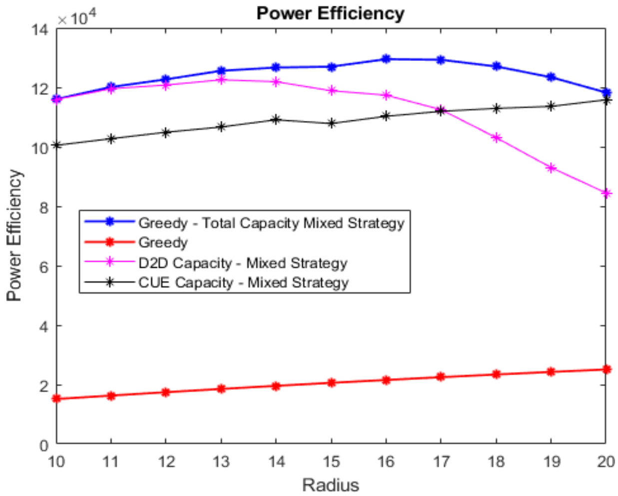

Figure 2. Power Efficiency Result

3.3 Spectral Efficiency Result

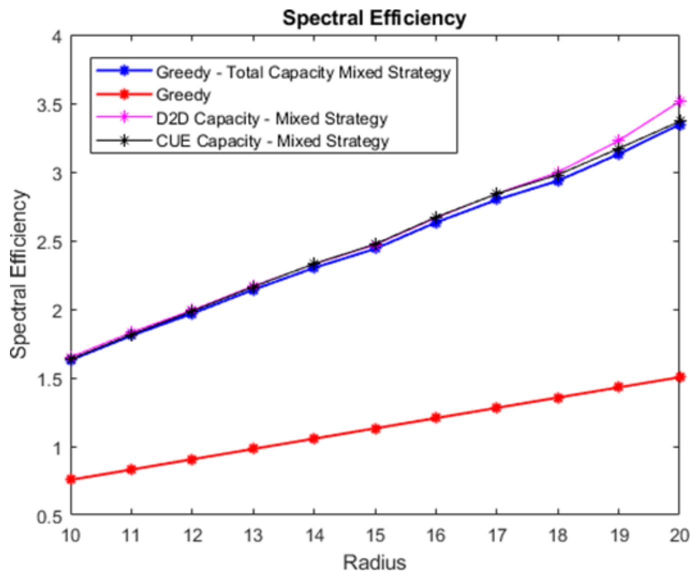

Figure 3. Spectral Efficiency Result

3.4 Total Power Used

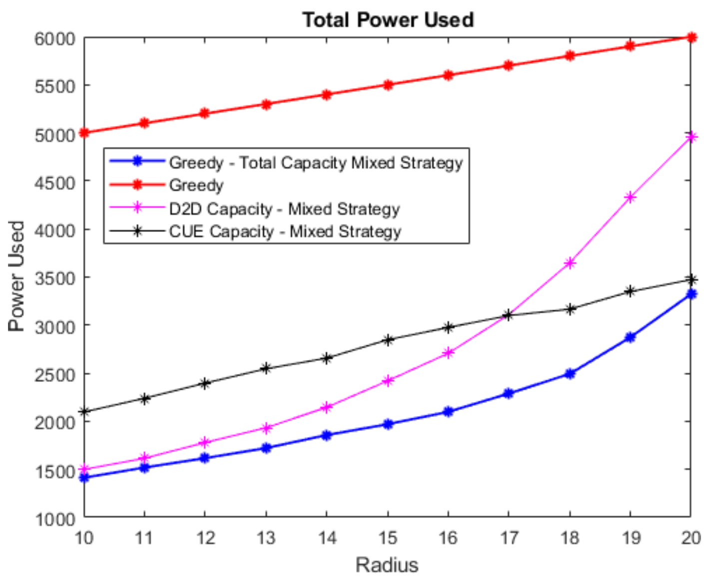

Figure 4. Total Power Used Result

4. Discussion

Based on graphic chart that shown in chapter 3, we can conclude that proposed mixed strategy algorithm successfully outperforms based model which only uses greedy algorithm for RB allocation. The result in term of value shown in **Table 2.**, **Table 3.**, **Table 4.**, and **Table 5**.

Table 2. Sum Data Rate Result

Algorithm	*Sumrate* (bps)	Percentage
Total Capacity Mixed Strategy	2.470×10^8	120.53%
D2D Capacity Mixed Strategy	2.490×10^8	122.32%
CUE Capacity Mixed Strategy	2.472×10^8	120.71%
Greedy	1.12×10^8	-

Table 3. Power Efficiency Result

Algorithm	*Power Efficiency* (bps/mWatt)	Percentage
Total Capacity Mixed Strategy	12.37×10^4	509.35%
D2D Capacity Mixed Strategy	11.15×10^4	449.26%
CUE Capacity Mixed Strategy	10.86×10^4	434.97%
Greedy	2.03×10^4	-

Table 4. Spectral Efficiency Result

Algoritma	*Spectral Efficiency* (bps/Hz)	Percentage
Total Capacity Mixed Strategy	2.321	107.04%
D2D Capacity Mixed Strategy	2.51	123.90%
CUE Capacity Mixed Strategy	2.326	107.49%
Greedy	1.121	-

Table 5. Total Power Used

Algoritma	*Total Power Used* (mWatt)	Percentage
Total Capacity Mixed Strategy	2106.61	-57.86%
D2D Capacity Mixed Strategy	2739.48	-45.21%
CUE Capacity Mixed Strategy	2804.23	-43.91%
Greedy	5000	-

5. Conclusions

The existence of 5G Underlay communication arises a hope of future communication which allows users communicate each other directly without passing eNB. The aim of this propose to make sure all RB are allocated along with the use of transmit power to transmit the data from Tx to Rx transmit well. The propose model successfully outperform baseline model in every performance parameters. For the sum data rate, our proposed model successfully outperforms baseline model up to 120.71%, for power efficiency result, our proposed model successfully has a higher result, up to 12.37 x 10^4 bps/mWatt. In term of spectral efficiency, out proposed model successfully outperforms baseline model by having up to 123.90% spectral efficiency, for total power sued, our proposed model successfully uses lesser power, up to 57.86% compared to baseline odel. Hopefully in future this model can be used also for deploying 5G conventional communication along with additional system to make sure the interference can be avoided.

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