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Resource Allocation and Mode Selection in 5G Networks Based on Energy Efficient Game Theory Approach

Amit Kumar Tiwari [1,2], Pavan Kumar Mishra[2], Sudhakar Pandey[2], Panduranga Ravi Teja[2]
[1]Deprtment of Computer Science & Engineering
United Institute of Technology
Prayagraj, India
kumartiwariamit@gmail.com
[2]Department of Information Technology
National Institute of Technology, Raipur
Raipur, India
pavanmishra.it@nitrr.ac.in, spandey.it@nitrr.ac.in, tejapanduranga@gmail.com

Abstract— With the advent of next-generation cellular networks, energy efficiency is becoming increasingly important. To tackle this issue, this paper investigates energy efficiency in D2D-enabled heterogeneous cellular networks. Boosting the longterm energy efficiency of wireless 5G communication networks is being explored through mode selection and resource allocation. The study proposed a three-stage process for energy-efficient mode selection and resource allocation. The process starts with cellular users who switch to D2D emitting a beacon and cellular users within close proximity reacting to it. A proposed auction mechanism will be enacted inside the group in the second state (in this paper, the group size will be four). Next, each cellular user was classified according to SINR values, distance, and battery life, so that they could dynamically transition between standard cellular mode and D2D mode. For stage three, direct-hop hybrid D2D communication, we developed a TAMM double auction game model that efficiently splits resources. To identify the true bidders in our game model, we compute the median and mode values of the ASK and BID values received by both seller and buyer cellular users. A simulation study shows that the proposed method is energy-efficient in a heterogeneous network enabled by D2D.

Keywords- Double auction game; energy efficiency; resource allocation; device-to-device (D2D) communication; mode selection; direct hop D2D communication.

I. Introduction

In 2020, there were more than 50 billion cellular devices that were linked. In the next ten years, data traffic will expand 1,000-fold [1, 2]. Numerous issues are brought up by this enormous development, including as spectrum limitations and higher power use. It is anticipated that the impending fifth-generation (5G) cellular network would allay these worries and enhance energy and spectrum efficiency. Long-Term Evolution Release 12 made the suggestion of D2D communication, which received a lot of attention (LTE-A). The ability of the technique to avoid Base Stations (BS), which enable direct communication between neighbouring devices [3],[4], has been shown. D2D users can utilise downlink (DL) and uplink (UL) to communicate while using one of three modes: 1) Orthogonal channels for D2D and cellular users in dedicated mode (DM) and overlay. Reuse mode (RS), also known as underlay, is a mode in which D2D uses CUE channels either during the UL or DL transmission. Cellular mode (CM), in which D2D users interact over the BS as ordinary CUE.

However, it is difficult to build an energy-efficient D2D communication due to the constrained user power, resource allocation, and co-channel interference for CU and D2D users. Incorrect selection of the user mode and allocation policy may cause severe interference and lead to extra energy consumption in base stations and devices. Above all, the first worry is identifying which user's equipment is required to operate in D2D and cellular mode. Thus, mode selection, resource algorithms allocation algorithms should be carefully designed to ensure the quality of service (quality of service) for mobile and D2D users to take full advantage of the communication in 5G networks.

Contributions

The literature study reveals that most prior studies examined preset D2D users and cellular users in the cell area. Significantly few researches indicated the parameters to flip the users' mode. Moreover, for assigning the resource to the D2D underlying cellular systems. This work tackles past research

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restrictions, and contributions of this work can be expressed as follows:

- The paper dealt with the problem of energy efficient mode selection using D2D communication.
- The paper acknowledged the resource sharing problem between cellular users and D2D communication to improve the system throughput.
- A practical network method is proposed for mode selection based on the classification algorithm in which users are classified as cellular users as sellers and D2D users as buyers, based on each user's distance, SINR, and battery life.
- We formulated a heuristic hybrid truthful median mode double auction game model algorithm to efficiently share the resources among cellular and D2D users.
- The proposed methodologies have been validated by a thorough simulation. We compared the results of the suggested strategy to the performance of the various works cited in the study. The simulation results imply that the recommended methods worked as intended.

The rest of the paper is structured as follows. The related work of D2D communication for mode selection and allocation of resources is presented in Section II. The contributions to this work are summarized in Section III. The system model and mathematic formulation are introduced in Section IV. Section V lists the intended works. Section VI presents the simulation results that were used to verify the suggested model. The paper is concluded in Section VIII.

II. RELATED WORKS

In the mode selection process, the users can choose whether to use a direct mode or a cellular mode, dedicated or reused. In general, depending on the time frame, mode selection could be static or dynamic. In order to handle network and wireless channel changes, dynamic mode selection may also be used, but the cost is an increase in processing and communication complexity. On the other hand, Static mode selection (such as distance-based mode selection) is consistent across time [5]. The authors investigated dynamic and static mode selection algorithms while accounting for user distance in the preceding work. However, distance is the essential element for switching modes, even though most research shows that the SINR and battery backup of CUs are critical criteria for effective communication.

In [6], [7], the authors investigated the theoretical analysis of user mobility mode selection. Researchers evaluated the received signal strength (RSS) as the choice metric for BS. The authors used a basic stochastic geometry model to investigate a distributed caching device-to-device network. A user's file of interest is cached in multiple chunks in the storage of other network devices. This mode selection procedure is more efficient, but it requires more processing and takes up more storage on each user's device, which adds complexity and may affect the system's overall performance. The authors of [8] offered a mode selection procedure based on a study of RSSs for D2D and cellular users, whereas the authors of [9] investigated RSSs for D2D-users combined with UL and DL. The writers of both articles have done considerable study on the received signal strength, but they have not taken into account the battery life of individual users. The authors of [10] created HetNet's users' selections to maximize RSS in DL transmission using a linear integer optimization. However, the author restricted his investigation exclusively to DL frequencies. The dynamic Stackelberg game framework has been proposed for linked mode selection and spectrum allocation in [11]. In [12], the authors offered a strategy to lower total transmission power based on a coalition between the D2D nodes. The authors used the distance between the D2D users as the sole criteria to establish the coalitions between them.

The main goal of D2D communication is to increase the network's throughput or spectral efficiency. Relays are employed to increase network coverage in the meanwhile. A cooperative game strategy was put forth in [13] to study the relay selection problem in cooperative D2D communication and to maximize the rate of each cooperative node. Nevertheless, energy efficiency and consumption are not included, which are significant markers of D2D communication in the 5G network. Improvements include the cooperative optimization of the power distribution of the D2D transmitter and D2D relay, which maximizes network energy efficiency [14]. Although the optimum system energy efficiency was examined, the multirelay selection was not involved. Therefore, the maximization energy efficiency problem of RA-D2D communication based on RS and power allocation (PA) was studied in [15]. However, TA was not fully utilized, because time slice resources were been fixed.

Along with the energy efficient mode selection, effective allocation of Resources in D2D is also one of the critical parameters in minimizing downlink reuse interference levels of cellular users. The authors proposed a next second-price auction and an iterative combinational auction for resource distribution between D2D and cellular users for a confined cell region in [16], [17], [18]. However, the authors of the preceding papers have not addressed the most common problems with the auction model, such as honest bidding procedures. Using resource allocation and mode selection, a power optimization method was created. To lower the DL transmission power [19]. To lessen disturbance to cellular customers, the Interference Limited Area (ILA) management

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system was created around D2D transmitters [20]. The D2D transmitter is not allowed to share the resources of CUEs that are located within its ILA in this article. The authors of [21] concentrated on increasing the energy efficiency of relays and D2D connectivity provided by HetNet. An energy-efficient self-organized cross-layer optimization strategy was proposed by the authors of [22], and [23]. Using a non-cooperative game, the authors independently addressed resource allocation and power optimization for D2D communication. This study did not consider the power management of Base stations, a critical factor in the declining D2D performance in downlink reuse.

III. SYSTEM MODEL

Acknowledge the proposed system model for cellular communication with Uplink / Downlink assignment. The network's system model is depicted in Figure 1. The eNodeB is placed at the cell's center. The devices are placed randomly over the entire cell area. The channel model considers CU and D2D users with dependent macroscopic path loss. The Rayleigh fading channel as well as its outcome are controlled by an independent complex Gaussian distribution.

The current 5G communication architecture is depicted in Figure 1.a, in which cellular users (CU1 to CU6) utilize individual resource blocks (RB1 to RB6) and the D2D pair (D2D1) uses a CU5 resource block.

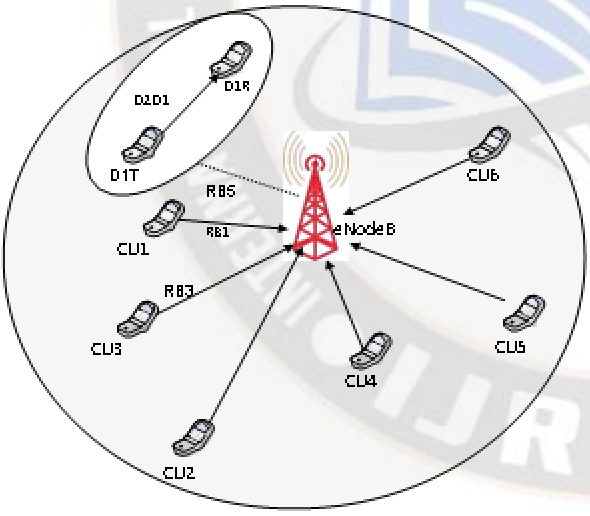

Figure 1. a Single-cell area with a single initially formed D2D pair

Figure 1. b depicts how cellular users CU2 and CU3 form a group and use the R3 resource block to send data to the eNodeB. CU5 and CU6 form a D2D group, and CU5 sends its data as well as CU6's data to the anode side through the RB5 resource block.

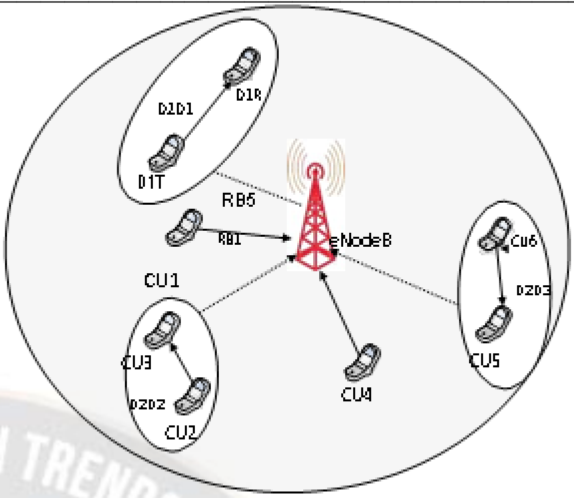

Figure 1. b Single cell area with three formed D2D pair

The SINR between the UE3 and BS/eNodeB in the uplink scenario is provided as

$$\delta_{U_3\_BS} = \frac{P_{U_3}.g_{U_3\_BS}}{\sigma^2 + \sum_{n=1}^{N} P_n.g_{n\_U_3} + \sum_{m=1}^{M} P_m.g_{n\_U_3}} \quad (1)$$

Similarly, the SINR between U4 to BS

$$\delta_{U_4\_BS} = \frac{P_{U_4}.g_{U_4\_BS}}{\sigma^2 + \sum_{n=1}^{N} P_n.g_{n\_U_4} + \sum_{m=1}^{M} P_m.g_{n\_U4}} \quad (2)$$

Finally, the SINR between U3 and U4

$$\delta_{U_3\_U_4} = \frac{P_{U_3}.g_{U_3\_U_4}}{\sigma^2 + \sum_{n=1}^{N} P_n.g_{n\_U_3} + \sum_{m=1}^{M} P_m.g_{n\_U_4}} \quad (3)$$

After obtaining the SINR value between CU3 and BS, CU2 and BS, and CU1 and CU4, the BS calculates the efficiency of all the cellular users and classifies them into seller and buyer cellular users. Based on CQI and device input, the BS assigned the resource. The eNodeB examines cellular customers' channel quality (SINR) in order to optimize the spectral performance of the network. For the seller cellular users, both sides of the channel must be good and close to the same quality. For buyer cellular users one side channel quality is higher than the other. In these conditions, the packet loss or network performance would suffer, and such users are preferred to share the resource with other users.

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Furthermore, these seller and buyer cellular users engage in the suggested double auction model to discover their corresponding user's pair and interact in D2D mode.

IV. PROPOSED METHOD

The proposed method is divided into two sections. The first section classified the users into the seller cellular users and buyer cellular users based on their SINR and battery life. In the second section, the seller and buyer users participate in the proposed double auction scheme and identify its pair for sharing the resources.

Section 1: Classifying the users into Sellers and buyer cellular users:

By categorising the users in the context of the dynamic network scenario, this section provides an effective mode selection strategy. Devices can roam in any direction in a dynamic network. As a result, the devices' communication distance might increase or decrease. Users who can exchange resources, such as devices with the highest SINR and battery life, function as sellers. The rest of the users act as buyers prepared to engage in Device-to-Device contact. Compared to CU communication, D2D communication delivers higher data speeds and lowers battery usage. The devices do not need to switch their mode of communication in the conventional communication system. This decreases throughput while increasing power consumption. A dynamic network mode selection mechanism has been suggested. A cell edge device starts communicating with another device near the BS when it is in CU mode. As soon as a communication device moves away from a nearby BS and toward the cell edge device, it will immediately change modes (CU to D2D mode). According to the channel quality indicator, the BS decides the maximum data rate (spectral efficiency) and the communication mode the device must use (CQI). The following variables influence the channel quality, which in turn determines the user requirements for both sellers and buyers.

$$\delta = \begin{cases} \delta_{U_3\_U_4} < \min\left(\delta_{U_3\_eNB}, \delta_{U_4\_eNB}\right) \text{ Seller Cellular Users} \\ \delta_{U_3\_U_4} \geq \min\left(\delta_{U_3\_eNB}, \delta_{U_4\_eNB}\right) \text{ Buyer Cellular Users} \end{cases} \tag{4}$$

Section 2: Truthful Ask Median Mode (TAMM) Double auction model:

In this section the buyer cellular users will send their series of bidding value strategies it made in a time 't' to the auctioneer (herein we considered the base station as the auctioneer to supervise the whole auction process) all the bid values are collected and sorted into an array as follows

$$B_n = \{b_1, b_2, b_3, b_4, \ldots.., b_n\} \tag{5}$$

Similarly, the series of asks to form the seller cellular users are taken as

$$A_m = \{a_1, a_2, a_3, a_4, \ldots.., a_m\} \tag{6}$$

The truthful buyer and seller are chosen by taking the median and mode value of the bids and asking strategies they made. Median and mode values for both buyer and seller strategies are given as follows

$$M_{BS} = \{M(B_n)\}, M_{AS} = \{M(A_m)\} \tag{7}$$

$$Mo_{BS} = \{Mo(B_n)\}, Mo_{AS} = \{Mo(A_m)\} \tag{8}$$

The truthful bid values for the buyer cellular users are now calculated as

$$\alpha = \begin{cases} 1 \;\; if \; \left(Mo(A_m) - \varepsilon\right) < M(B_n) > \left(Mo(A_m) + \varepsilon\right) \\ 0 \;\;\; elsewhere \end{cases} \tag{9}$$

$$T_B = \left(M\left(B_n\right)\alpha\right) \tag{10}$$

The truthful ask values for the seller cellular users are now calculated as

$$\alpha = \begin{cases} if \; \left(Mo(B_n) - \varepsilon\right) < M(A_m) > \left(Mo(B_n) + \varepsilon\right) \\ 0 \;\;\; elsewhere \end{cases} \tag{11}$$

$$T_A = \left(M\left(A_m\right).\alpha\right) \tag{12}$$

Where α is the negotiation parameter, and ε is a constant variable

V. SIMULATION RESULTS

In a dynamic network environment where communicative devices are allowed to travel and adjust their location in communication, we evaluate the performance of our suggested mode selection and resource allocation scheme to a conventional mode selection method. On a MATLAB simulator, the simulation is run.

Table 1 lists significant simulation parameters and their default values. We run our software numerous times to draw the graph, then average the results. Devices are unrestricted in communication and can move at regular speeds. The gadgets are placed in the cell area at random.

1) Table 1. ***Simulation Parameters***

S.No	PARAMETER	VALUE
1	Cell Radius	300m
2	Max. Trans. Power eNB	200mW
3	UE Trans. Power	26 dBm
4	eNB Trans. Power	46 dBm
5	Device noise figure	-175 dBm/Hz
6	Proximity Distance	50 meters
7	Bandwidth	20 MHz

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The graph in Figure 2 compares the simulation times taken by the conventional mode selection approach with the suggested mode selection method. When the number of cellular users is low, the suggested technique takes a little longer to process at first. However, as compared to the usual way, the suggested method takes much less time as the number of cellular users grows. Due to the dynamic nature of the network, devices are free to roam around while communicating and can change their mode. As a result, after 100 simulations, we discovered that the communication devices switch to a better mode. As shown in Figure 2, the throughput of our suggested technique outperforms that of conventional mode selection

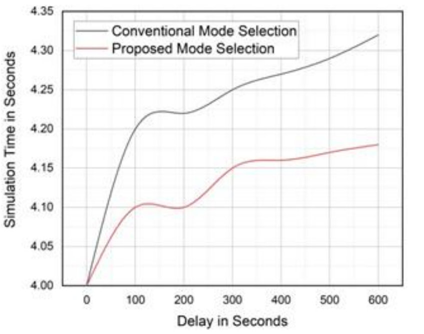

Figure 2: *Comparison of Delay in seconds*

Figure 3 depicts a graph of energy use vs. the number of cellular users. When compared to cellular communication, D2D communication uses less energy (CU). By changing their mode, the devices in our approach can start D2D communication when they are near to one another (in a proximity zone), which reduces their transmission power. In comparison to traditional mode selection, the suggested techniqueproduces superior results.

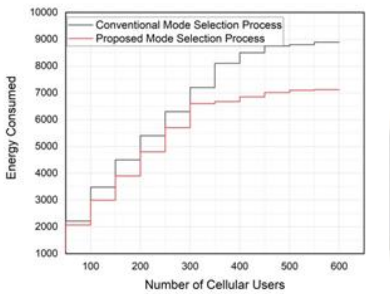

Figure 3: *Energy consumed by number of cellular users*

Figure 4 depicts a graph of resource blocks used to communicate vs. the number of cellular users. When compared to cellular communication, D2D communication share the resource blocks with cellular users. Devices in our technique may alter their mode to D2D, which utilizes the resources form the eligible cellular users. In comparison to traditional resource sharing techniques in proposed techniques a greater number of users participate in sharing the resources in regard of truthful bidding strategies. As a result, as the number of cellular users in the cell area increases, so does the possibility of forming D2D pairs. In addition, as compared to typical resource allocation strategies, the resources were used more efficiently.

The graph of the number of cellular users vs. throughput is shown in Figure 5. Because the communicating devices employ the same form of communication, the throughput of both ways is initially similar. We accomplished the utmost truthful bidding strategies by the participants in the suggested resource allocation double auction technique, which maximizes the number of cellular users who switch their mode of communication to D2D and allows more users to fit into the cell area. Nonetheless, in the suggested mode selection model, we categorized users as sellers and buyers based on their SINR and battery life, so that only those who are qualified can share their resources. As shown in Figure 6, the throughput of our suggested technique outperforms that of conventional resource allocation truthful double auction models

Figure 6 shows the comparison of the users' probability of truthful bidding strategies between the conventional truthful double auction model and the proposed truthful median mode double auction model. The proposed model filters the ASKs strategies in two stages by calculating their median and mode. This process allows the users to bid truthfully and eliminates the false strategies

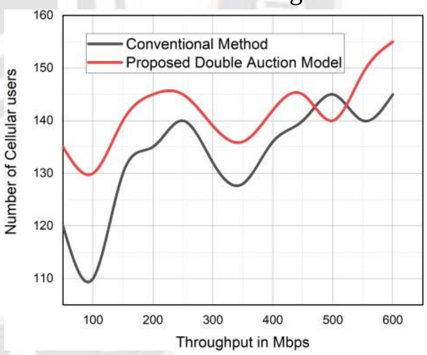

Figure 5: *Total system throughput*

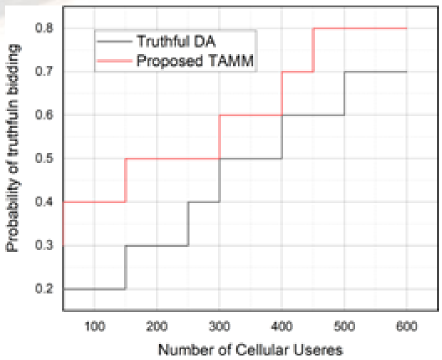

Figure 6: Probability of Truthful bidding

VI. CONCLUSION

Local communication in a cellular network is improved by D2D communication, which also reduces end-to-end latency and battery consumption while increasing spectrum efficiency and network throughput. Devices begin commutations in CU mode at first, but when they get closer to one other or near the cell edge, throughput begins to drop. In this research, we suggested an efficient mode selection mechanism and an efficient resource allocation technique for dynamic networks. The communication devices examine the SINR value and battery life for mode selection after a predetermined interval. This method also takes into account device distance, path loss, and interference from other devices. The performance outcomes of our suggested technique surpass those of traditional methods.

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