IJMRSETM

e-ISSN: 2395 - 7639

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING, TECHNOLOGY AND MANAGEMENT

Volume 9, Issue 7, July 2022

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.580

+91 99405 72462 +9163819 07438 ijmrsetm@gmail.com www.ijmrsetm.com

International Journal of Multidisciplinary Research in Science, Engineering, Technology & Management (IJMRSETM)

| ISSN: 2395-7639 | www.ijmrsetm.com | Impact Factor: 7.580|

| Volume 9, Issue 7, July 2022 |

| DOI: 10.15680/IJMRSETM.2022.0907028 |

DEVICE-TO-DEVICE (D2D) COMMUNICATION

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ABSTRACT:
In the fifth generation of wireless networks, Device-to-Device (D2D) communication is anticipated to play a significant role in increasing system capacity. Gains are anticipated as a result of the potential for resource reuse that was allotted to cellular users (CUs) for the D2D underlay network. This permits resource redistribution within the same cell and may cause significant interference. The main difficulty is coming up with resource allocation plans for D2D communication that don't negatively impact CU's communication. Resource allocation may be used to accomplish a variety of performance goals, such as increasing network throughput, reducing delays, and establishing equity across user data rates, among others. Our goal in this study is to put forward a polynomial time proportional fair (PF) resource allocation plan that complies with the CUs' rate criteria. The suggested plan may possibly be used with any CU resource allocation plan and can adjust to the channel circumstances that change with time and place. A D2D pair may get more than one resource block under our system. The simulations are used to verify the proposed scheme's performance.

I. INTRODUCTION

Device-to-Device (D2D) communication refers to a technology that enables devices to communicate directly with each other, without sending data to base station and the core network. This technology has potential to improve system performance, enhance user experience, increase spectral efficiency, reduce the terminal transmitting power, reduce the burden of cellular network, and expand cellular applications(Andrews, 2014; Feng, 2014; Rebecchi, 2015; Tehrani, 2014).

| ISSN: 2395-7639 | www.ijmrsetm.com | Impact Factor: 7.580|

| Volume 9, Issue 7, July 2022 |

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Typical D2D applications include cellular-assisted D2D communications and Vehicle-to-Vehicle (V2V) direct communications. Other potential applications include public safety support, where and when the radio infrastructure is not available due to damage, for example. Cellular-assisted D2D communications enables terminals to multiplex cell resource for direct communications but under the control of a cellular system. In such a setting user data can be directly transmitted between terminals without routing via the data paths through BSs and core network. D2D communications introduces new challenges to the device and network design. It will introduce interference to cellular communications as D2D multiplexes cellular resources and will bring new security and mobility management challenges.

Mobility

In cellular communications, the Base Station (BS) is fixed and UEs are moving while in D2D communications the source and destination nodes are able to move and the mobility range of D2D connection is limited because of limited transmission power so it is suitable only for short-range communications where D2D communications have higher data rates, lower mobile transmit power and usually small path-loss.

Transmission Mode selection

In D2D communication UEs are enabled to select among different Transmission Modes (TM) which are defined based on the frequency resource sharing. Figure 0.1 shows the TMs in D2D enabled 5G network.

• Dedicated mode where the D2D communication is direct and data is transmitted through the D2D link by the orthogonal frequency resources to the cellular users so there is not any interference.

• Reuse mode where data is transmitted through the D2D link by the reusing the same frequency resources that are considered for a cellular user or another D2D link so the reused mode causes interference at receivers. However, the system spectrum efficiency and user access rate may be increased.

| ISSN: 2395-7639 | www.ijmrsetm.com | Impact Factor: 7.580|

| Volume 9, Issue 7, July 2022 |

| DOI: 10.15680/IJMRSETM.2022.0907028 |

• Cellular mode where the D2D communication is relayed via eNB and it is treated as cellular users (Hakola, 2010).

Problem statement

In D2D communications, data can be directly transmitted between terminals without routing via the data paths through BSs and core network. D2D communications introduce new challenges to the device and network design such as the optimization of power consumption, resource allocation and mobility management challenges.

II. LITERATURE REVIEW

In this work, we study the problem of mode selection in D2D enabled networks. In the first phase, we address the problem of mode selection policy. For this purpose, we present a model with two flows: cellular and D2D (dedicated and reused) and the resulting policy which transmission mode should be selected.

The problem is formulated as a Markov Decision Process with the objective of maximizing the total expected reward of the system. The value iteration algorithm is used to compute a stationary deterministic policy.

In the second phase, the problem of mode selection for mobile UEs is discussed. We develop a mobility based mode selection algorithm for the case where all of UEs move in a single cell. In our proposed algorithm we consider QoS parameters and UEs velocity and then we utilize Analytic Hierarchy Process (AHP) to add weights to the criteria.

III. CONFIGURATIONS OF D2D COMMUNICATION

Various configurations [3] of the D2D networks are available, as follows:

- Network-controlled D2D: The base station and the core network are in charge of setting up the signalling system and then allocating resources to the D2D pairs and CUs. Resource allocation and interference management may be more effective as a consequence of the centralised control.
- Self-organized D2D: The nature of this configuration is scattered. Similar to cognitive radio (CR), D2D users are able to detect spectrum gaps, gather channel state

| ISSN: 2395-7639 | www.ijmrsetm.com | Impact Factor: 7.580|

| Volume 9, Issue 7, July 2022 |

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information (CSI), and identify potential interferences. They then interact with other D2D pairs in a self-organizing manner. So, although it lowers signalling overhead, the absence of centralised supervision might lead to instability.

- Network-assisted D2D: In this case, the BS just provides resources to the D2D users; after that, the users organise their communication in a self-sufficient manner. Security might be a possible concern, however this system provides minimal signalling cost and some centralised management to prevent communication anarchy.

IV.SCHEDULING TECHNIQUES IN CELLULAR NETWORK

A difficult optimization challenge arises in wireless communication systems due to the need to concurrently and reliably offer numerous users with high-rate communication channels. In the face of time-varying and frequency-selective channels, questions of resource block assignment, interference, and power consumption at the BS and mobile devices must be addressed. Furthermore, different devices and applications may demand quite different amounts of latency and data rate. These needs and queries might be expressed as resource allocation issues.

Allocating radio resources to users is the responsibility of the medium access control (MAC) scheduler, a crucial component of the BS. Before making any scheduling decisions, CSI, rate requirements, and user fairness are all taken into consideration. Maintaining QoS for all user needs in long-term evolution (LTE), an all-IP network, is a key challenge. Therefore, the QoS requirements of the CUs must be taken into consideration by the LTE MAC scheduler. Since radio resources are limited, they must be distributed to consumers effectively. Before analysing the scheduling of D2D users, we must assess the effectiveness and usefulness of the currently used scheduling methods. offers an overview of the LTE scheduling methods currently in use.

In LTE networks, three fundamental scheduling techniques, namely round robin (RR), maximum rate (MR), and proportional fair (PF), may be employed. They may be contrasted in terms of user fairness and network speed.

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V.FORMULATION OF THE PROBLEM

We assume that the eNodeB schedules CUs in each sub-frame n using an existing online or offline scheduling mechanism. We now wish to provide D2D pair d the same resources as CU c. This resource allocation issue is formulated as an optimization issue. We presum e a time division duplex (TDD) system with an identical split of the resources between the uplink and the downlink. Assume that there are M and N, respectively, available resource blocks for the uplink and downlink. In our scenario, we assume that the receiver has perfect CSI. Therefore, when scheduling choices are made, the BS is aware of all channel gains between the BS and CUs, those between D2D users, the interfering connections between the BS and D2D transmitter, as well as the link between the CU and the D2D receiver. The number of users in the cell is assumed to be constant, and each user has a finite quantity of data to send in each sub-frame. Let C = f1 be the set that the eNodeB serves. . . NC g of CUs, together with a set D = f1. . . pairings of D2D, ND g. Since it is realistic to assume that there are more CUs than D2D pairings in a cell, we also assume NC ND.

transmit powers are xed. Now, if the d^{th} D2D pair shares same downlink resource blocks as the CU c, the received SINR of the CU c is given by,

$$c^{DL} = \frac{P_B g_{Bc}}{N_0 + P_d x_c^d P_d g_{cd}} : \qquad (2.1)$$

Similarly, the received SINR at the d^{th} D2D receiver is given by,

$$^{DL} = \frac{c\, x_c^d P_d g_{dd}}{N_0 P_c\, c\, B\, g_{Bd}} \qquad (2.2)$$

Here, N_0 denotes the thermal noise power spectral density at the receiver and the optimization variable x^d_c is an indicator function de ned as,

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X XX

Maximize $m_c r_c^{DL}$ + $x^d{}_c m_c r_d^{DL}$; (2.3)

c d c

P g DL N + x^dP g ; 8c 2 C; (2.4)

B Bc c;tgt 0 c d cd

Xc $x_c^d P_d g_{dd}$ d;tgt^{DL} N_0 + X c $x_c^d P_B G_{Bd}$; 8d 2 D; (2.5)

Xc x_c^d 1; 8d 2 D; (2.6)

Let, r_c^{DL} and r_d^{DL} represent the rates corresponding to the SINRs$_c^{DL}$ and$_d^{DL}$ respectively as determined by the Shannon's Capacity Theorem. The goal here is maximize total system sum throughput constrained on satisfying minimum rate requirements of both CUs and D2D pairs. For simplicity, we assume maximum one CU can share its resource blocks to one D2D pair and vice versa. Then, in the sub-frame n, the resource allocation problem can be formulated [10] as an optimization problem given as,

X XX

Maximize $m_c r_c^{DL}$ + $x^d{}_c m_c r_d^{DL}$; (2.3)

c d c

P g DL N + x^dP g ; 8c 2 C; (2.4)

B Bc c;tgt 0 c d cd

Here, m_c denotes the number of downlink resource blocks allocated to the CU c in sub-frame n. Also,$_{c;tgt}^{DL}$ and$_{d;tgt}^{DL}$ denote minimum target SINRs of CU c and D2D pair d respectively. Equations 2.4 and 2.5 ensure maintaining minimum rate

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| Volume 9, Issue 7, July 2022 |

| DOI: 10.15680/IJMRSETM.2022.0907028 |

requirements for both CU c and D2D pair d, while Equations 2.6 and 2.7 ensure that one D2D pair can be allocated at most one CU's resources and one CU can share its resources to at most one D2D pair respectively.

2.3.1 Analysis of Downlink Resource Allocation

In the downlink situation, CU is subject to interference from the D2D transmitter, and the D2D receiver, assuming they share the same radio resources, is subject to interference from the eNodeB. The transmit power of the gadget or eNodeB, as well as the channel gains between them, determine this interference. Let gBc stand for the channel gain between the eNodeB and CU c, gBd for the channel gain between the eNodeB and D2D user d, and gdd for the channel gain between D2D pair d. Let PB, Pc, and Pd stand for the corresponding transmit powers of the eNodeB, CU, and D2D transmitters. Assuming no power control also, all the

2.3.2 Analysis of Uplink Resource Allocation

In the uplink situation, eNodeB is susceptible to interference from the D2D transmitter, and the D2D receiver, assuming they share the same radio resources, is susceptible to interference from CU. The received SINR at the eNodeB is provided by, if the dth D2D pair has the same uplink resource blocks as the CU the c.

Let rBUL and rdUL be the rates that, according to Shannon's Capacity Theorem, correspond to SINRs BUL and dUL, respectively. Maximizing overall system throughput while still meeting the minimum rate demands of both CUs and D2D pairs is the objective here. For the sake of simplicity, we'll suppose that a CU can only share one D2D pair's resource blocks with another CU at most. The resource allocation issue may therefore be expressed [10] as an optimization problem using the following formula:

$$_{B}^{UL} = \frac{P_c\, g_{Bc}}{N_0 + P_d\, y_c^{d} P_d g_{Bd}} :$$

Similarly, the received SINR at the d^{th} D2D receiver is given by,

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$$P_{C;} g_{cBc} \quad {}^{UL}_{B;tgt} \quad N_0 + \quad y^d P_c g_{dBd} \quad ; \quad 8c\,2 \qquad (2.11)$$

$$X_c \quad y_c{}^d P_d g_{dd} \quad {}_{d;tgt}{}^{UL} N_0 + X_c \quad y_c{}^d P_c g_{cd} \; ; \; 8d\,2\,D; \qquad (2.12)$$

$$X_c \quad y_c{}^d \quad 1; \; 8d\,2\,D; \qquad (2.13)$$

$$\text{and} \quad X_d\, y_c{}^d \quad 1; \quad 8c\,2\,C: \qquad (2.14)$$

Here, n_C denotes the number of uplink resource blocks allocated to CU c in sub-frame n. Also,${}_{B;tgt}{}^{UL}$ and${}_{d;tgt}{}^{UL}$ denote the minimum target SINR of CU c and D2D pair d respectively. Equations 2.11 and 2.12 ensure maintaining minimum rate

requirements for both CU c and D2D pair d, while Equations 2.13 and 2.14 ensure that one D2D pair can be allocated at most one CU's resources and one CU can share its resources to at most one D2D pair respectively.

2.4 An Algorithm for Greedy D2D User Scheduling

Mixed integer non-linear programming is used to solve the aforementioned optimization issues for the uplink and downlink situations (MINLP). We may use a suboptimal greedy heuristic approach to distribute resources among D2D users since it is difficult to provide an ideal solution during a scheduling period of 1 ms. The following are the suggested algorithms:

According to Equation 2.1, the greater the channel gain between CU and eNodeB or lower the channel gain between CU and D2D pair sharing the same radio resources, the higher the system cumulative throughput for the downlink scenario. Therefore, it makes sense that a CU with a high channel quality indicator (CQI) might share its resource blocks with a D2D pair while still experiencing the least amount of interference

Similar to the downlink case, we can see from Equation 2.8 that the greater the channel gain between CU and eNodeB sharing the same radio resources and the lower the channel gain between D2D pair and eNodeB, the higher the system cumulative throughput. Therefore, it makes sense that a CU with a high CQI might share its resource blocks with a D2D pair as long as it interferes with eNodeB on those resource blocks as little as possible.

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VI.SIMULATOR CONFIGURATION

System level simulations have been carried out in MATLAB to assess the performance of the greedy heuristic approach. A single hexagonal cell with an ISD of 500 m has been taken into consideration. Consideration has been given to omnidirectional Single Input Single Output (SISO) antenna configuration. Both the uplink and downlink situations are taken into consideration, with a system bandwidth of 10 MHz. Within the cell, CUs and D2D transmitters are scattered evenly. We define the D2D communication range, or RD2D, as the separation between the D2D transmitter and receiver. Within a predetermined area, D2D receivers are evenly dispersed around the D2D transmitters. We change it from 5 m to 50 m in stages of 5 m to better understand the system level performance with various values of this range. Each RB has a total of 12 contiguous sub-carriers that are grouped together for the length of one Transmit Time Interval (TTI), or 0.5 millisecond, and 6 or 7 OFDM symbols. Each sub-frame of the length two TTIs is where scheduling choices are made (1 millisecond). Due to its qualities of having a low peak-to-average power ratio (PAPR) and physical requirements requiring resource blocks given to a single user to be continuous in frequency, SC-FDMA is used in LTE as the multiple access technique for the uplink. However, owing to the use of orthogonal frequency division multiple access (OFDMA) technology, there is no such restriction on the distribution of contiguous bandwidth for the downlink. All possible sub-carriers are regarded to have the same power performance. In Table 2.1, all simulation-related parameters are enumerated.

Parameter	Values
Cell layout	Single Hexagonal cell
Inter-site distance (ISD)	500 m
Available spectrum (UL/DL)	10 MHz
Number of subcarriers per RB	12
Subcarrier spacing	15 KHz
RB bandwidth	180 KHz
Number of RBs	50
eNodeB transmit power	20 W
UE (CU/D2D) transmit power	250 mW

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Modulation and coding scheme (MCS)	QPSK: 1/6, 1/3, 1/2, 2/3 16QAM: 1/2, 2/3, 3/4 64QAM: 1/2, 2/3, 3/4, 4/5
Sub-frame duration	1 ms
Number of symbols per slot	7 (1 pilot+6 data)
Cell-level user distribution	Uniform
Number of active CUs	10, 20, 30, 40, 50
Number of active D2D pairs	10%, 20%, . . . 50% of active CUs
User speed	Static
Log-normal shadowing standard deviation	8 dB
Distant dependent Path loss	PL = 128.1 + 37.6log(d)
UE noise gure	5 dB
UE thermal noise density	-174 dBm/Hz
Antenna layout	Omni-directional antenna
Tra c model	Full bu er tra c

Table 2.1: Values and settings for simulation.

Table 2.2 compares the network performance with and without D2D communication, showing the percent improvement in overall network throughput. Table entries for various D2D ranges have been produced, with ND = 20 for the number of D2D pairs and NC = 100 for the number of cellular users.

Range of D2D communication (m)	% increase in throughput in downlink	% increase in throughput in uplink
5	39.82	45.61
10	31.34	36.46
15	26.47	31.12
20	23.09	27.35

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25	20.53	24.45
30	18.47	22.10
35	16.77	20.13
40	15.32	18.43
45	14.06	17.48
50	12.95	15.65

Table 2.2: % increase in network throughput for di erent range of D2D communication (N_C = 100, N_D = 20).

VII.CONCLUSIONS

Using the excess SINR of CUs above their required SINR threshold, we allocate powers to D2D pairs in this work to ensure that the minimum SINR of CUs after the inclusion of D2D pairs can still be maintained. Based on this concept, we then determine the best pairing between resource blocks and D2D pairs using a bipartite graph based matching algorithm to ensure that each D2D pair gets at most one resource block

This work can be extended to verify how the proposed resource allocation scheme works in a guaranteed bit rate real-time application by varying the number of maximum allowable resource blocks that can be allocated to a D2D pair. Future work involves simulation of the proposed algorithm in a multi-cell scenario, by considering inter-cell interference.

The cellular network's underlying D2D communication may increase system capacity and spectral efficiency, but adding D2D users might seriously interfere with CUs' ability to communicate. As a result, effective D2D resource allocation methods must be developed to improve spectral efficiency while also reducing disturbance to the CUs in order to preserve their QoS. In this thesis, we address this issue and provide brand-new resource allocation techniques for the D2D underlay network.

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For the D2D underlay network, we have examined interference possibilities in Chapter 2 for both the uplink and the downlink. In order to schedule D2D users while preserving QoS for both cellular and D2D users, we have suggested a greedy heuristic technique. According to simulation studies, adding D2D users increases network capacity compared to the current cellular network. Power management for D2D users and extending this study in a multi-cell environment by taking into account inter-cell interference are two potential research directions

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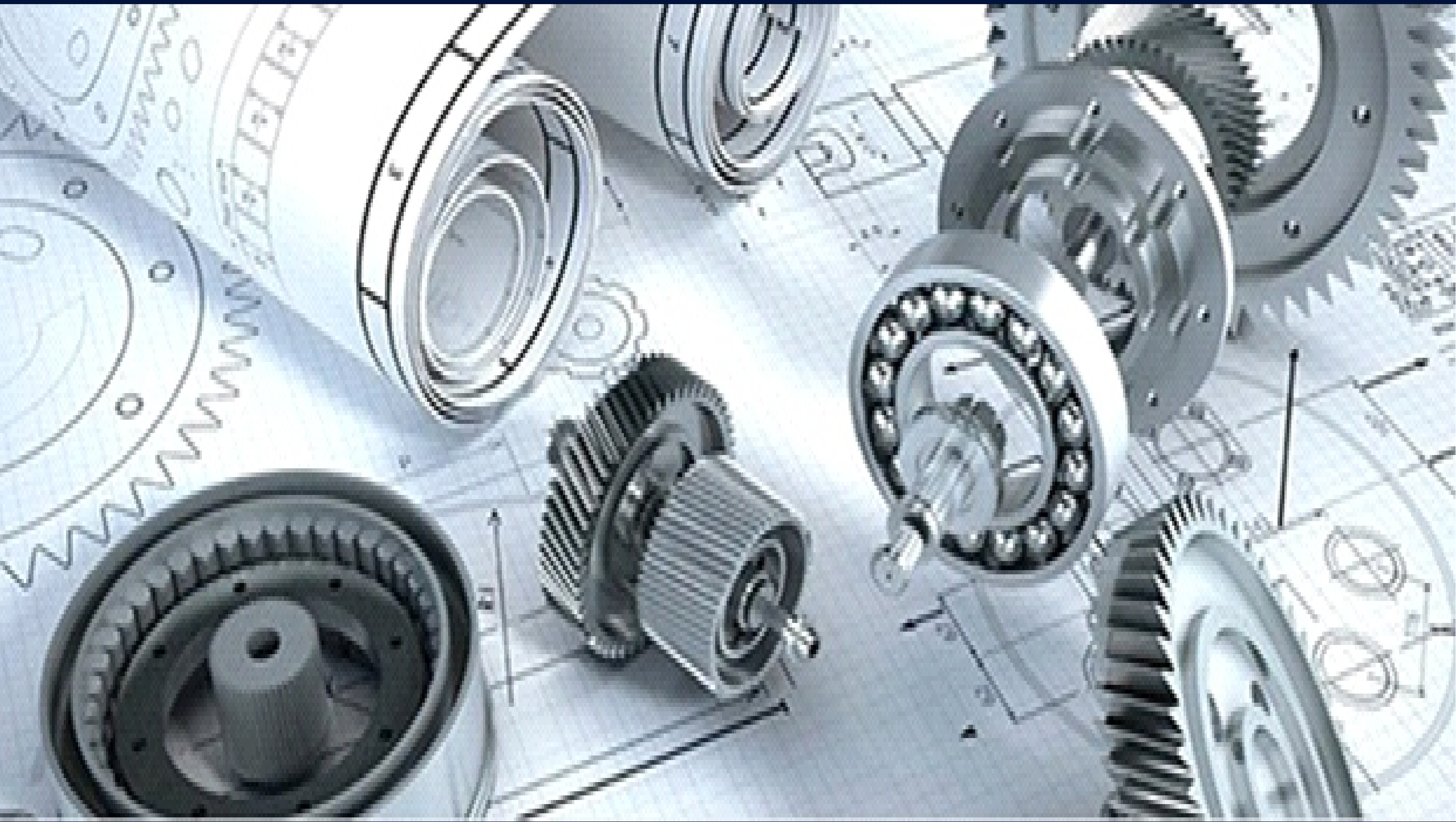

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