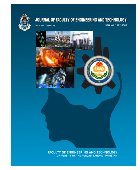
JFET 24(2) (2017) 67-77

Journal of Faculty of Engineering & Technology

journal homepage: www.pu.edu.pk/journals/index.php/jfet/index



SPECTRAL EFFICIENCY ENHANCEMENT IN DEVICE-TO-DEVICE NETWORKS

R. Masroor[*1] , M. Zulfiqar[2], M. Abrar[3]

[1,,3] Department of Electrical Engineering, UCE&T, BZ University, Multan, Pakistan
[2] Department of telecommunications, BZ University, Multan, Pakistan

Abstract

This paper investigates the comparative analysis of two In-band Device to Device (D2D) modes, namely Underlay and Overlay in the future 5G cellular wireless systems laying D2D networks. Different resource allocation algorithms, Round Robin (RR), maximum SNR (MS) and Proportional Rate (PR) are investigated. Three modes of resource allocation namely Reuse Mode, Dedicated Mode-I and Dedicated Mode-II are presented for Underlay and Overlay D2D communication simultaneously. System throughput has been maintained between cellular users and D2D users through these schemes. Further all three schemes are compared in Reuse mode. Simulation results have been presented to verify the investigated algorithms.

1. Introduction

In modern technology, there is a fast growth in wireless communication system from last two decades, starting from analog mobile radio systems as 1st Generation (1G) to current 4th Generation (4G). A lot of work has been done on the development of Third-Generation Partnership Project (3GPP), Long term Evolution (LTE) and LTE-Advanced (LTE-A) for higher system capacity, higher data rates and improved spectral efficiency [1]. Aggrandization of cellular users has forced telecom operators to put attention towards device to device (D2D) communication. It is basically a wireless transmission in which one device is connected to base station (BS) and other devices gain signal from the connected one. It is a non-transparent procedure to cellular operators. It creates an infrastructure-less environment which attract the operators most. Researchers want to utilize its full advantages. So, they have further classified D2D into two flavors i.e. In-Band and Out-Band. In-Band deals with cellular spectrum while Out-Band deals with cellular Spectrum and Industrial, scientific and Medical Radio Frequency band (ISM). In former type of D2D, it is again categorized into two types; underlay [1] and overlay [2]. In underlay, Cellular user and D2D are both using the same resources while in overlay cellular user and D2D both uses dedicated resources. Its implementation is still facing many issues i.e. interference [3],[4] and power consumption[5],[6]. In cellular networks, users of mobiles use high data rate services (e.g., public networking, betting, sharing of video, gaming etc.) these services are in the range of direct communications (i.e., D2D). Communication between D2D is one that comes in next generation. So, Device-to-Device communication is the direct communication among two users of mobile with no or minor involvement of BS. The advantages of D2D communications are increasing spectral efficiency, enhancing throughput, energy and power efficiency, improve interference and networking performance [1-2].

* Corresponding Author: roohamasroor@gmail.com

In D2D communications the interference is a challenging factor for both cellular and D2D communication and leads to low Quality of Service (QoS) and high packet loss rate. To solve these issues by many possible remedies have been proposed on interference management, power control, resource allocation, various interference avoidance, proper mode selection and advanced coding schemes [3-7]. D2D communications perform as an underlay to the modes of operation in cellular network, which can attain restricted short-range direct transmission of data for local region services by reusing the spectrum, it is important to improve the spectral efficiency and throughput. Dedicated mode is used to optimize the sum rate of transmission between D2D [8]. However, selection of modes and reusing of resources are the challenging factors for D2D communication.

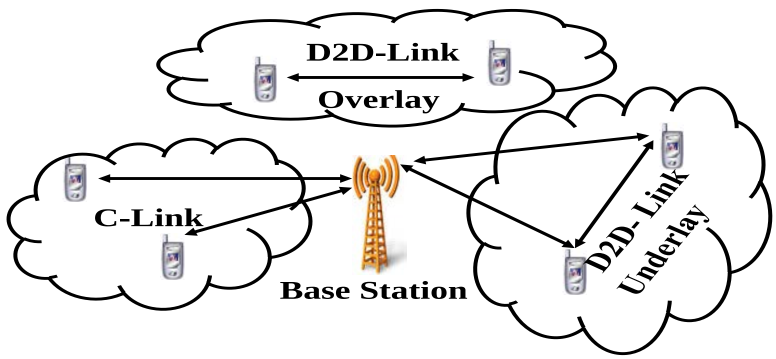


Figure 1. D2D-enabled Cellular Network

Despite all this, studies fail to provide comparative analysis of underlay and overlay D2D communication in cellular networks. In this paper, motivated by the promising performance of D2D communication we provide comparative analysis of both In-band techniques using proportional fairness allocation of resources. The paper is organized as follow. Section II provides some insight about the research work done related to the topic. We describe the system model in Section III. While and problem formulation is presented in Section IV. Different algorithms are also presented in section IV. In section V, we present numerical result followed by conclusions in section VI.

2. Related work:

Recently, there has been a huge interest in increasing the network throughput of D2D communication in cellular networks, which is treated as a fundamental performance metric. Interference is a major challenge in underlay as both the users are using same resources. Researchers have done a lot of work in term of different strategies to solve this problem. Authors of [7] have resolved the problem through game theory. It is sequential second price auction method in which a unit is further divided into small homogenous units. Then, it will be easy to make a bid on each block and to sale it. Authors of [8] have alleviate the problem through location strategy. In this scheme, Global positioning system gathers the information of free users. Then, it detects how much D2D's are linked. Graph theory is another technique to analyse resource allocation problem. Researchers of [9] have used graph theory to reduce interference level between different D2D broadcast group. Interference avoidance has done in [10] through frequency domain scheme where orthogonality of users are offer. The authors in [11] have dealt through interference coordination mechanism in which cellular users are given priority. It also controls power with maximizing D2D links. Further, quality of service and throughput can be maintained through resource allocation algorithm in which a single user is sharing resources with one or more D2D [12]. Distance based algorithm is proposed in [13] to measure the distance between D2D, CU and base station. Distance measurement is done to remove interference between them. Other parameters like system throughput and spectrum efficiency [14] is improved in order to get maximum sharing of resources. Lagrangian dual method and karush Kuhn-Tucker method is used to increase resource blocks utilization which results in system throughput and increased sum-rate. Three in one solution i.e. power control, mode selection and resource allocation is controlled through poison point process and Rician fading scheme.

3. Frame work:

A. System Model:

In this paper, we consider a scenario as shown in Fig. 1, where mobile users are divided into two categories, cellular users (CUEs) and D2D users (DUEs). Conventional CUs communicate directly to Base station (BS). In comparison, two nearby DUs communicate locally to exchange information with each other. For underlay D2D communication reuse mode is used for D2D link and there are no dedicated resources available for D2D link. While two dedicated modes are introduced when D2D devices are in overlay mode. Totally, *N* CUEs, and *M* DUEs are being considered in a single cell environment.

B. Mathematical Formulation

For convenience, uplink transmission is only considered in this paper for both underlay and overlay communication. In underlay communication let, $SNR_{c,n}$ and $SNR_{d,m}$ are the received signal to Interference-noise ratio (SINR) at BS and at mth DUE_R and can be expressed by:

$$SNR_{c.n} = \frac{P_{c,n}\left|H_{c,n}\right|^2}{P_{d,m}\left|H_{d,m}\right|^2 + n_0} \quad (1)$$

$$SNR_{d,m} = \frac{P_{d,m}\left|H_{d,m}\right|^2}{P_{c.n}\left|H_{c,n}\right|^2 + n_0} \quad (2)$$

The sum-rate in uplink transmission for underlay can be expressed as;

$$R_{m,n}^{under} = log_2(1 + SNR_{c.n}) + log_2\left(1 + SNR_{d,m}\right) \quad (3)$$

In overlay communication, the signal-to-noise ratio (SNR) at BS and at mth DUE_R can be expressed as $snr_{c,n}$ and $snr_{d,m}$ respectively and given by:

$$snr_{cu.m} = \frac{p_{c,n|h_{c,n}|^2}}{n_o} \quad (4)$$

$$snr_{dtx,n} = \frac{p_{d,n|h_{d,n}|^2}}{n_o} \quad (5)$$

The sum-rate in uplink transmission for overlay can be expressed as

$$R_{m,n}^{over} = log_2(1 + snr_{c.n}) + log_2\left(1 + snr_{d,m}\right) \quad (6)$$

Where $P_{c,n,}$,$p_{c,n,}$: Power of CUEs

$H_{c,n}$, $h_{c,n}$: channel vectors for CUEs Transmission

$P_{d,m}$,$p_{d,m}$: Power of DUEs

$H_{d,m}$, $h_{d,m}$: channel vectors for DUEs Transmission

$D_{dtx,m}$: Symbol of *m*th $\mathrm{DUE}_{\mathrm{T\ data}}$

n_o: Noise Factor

4. Problem Formulation:

A. Overlay D2D Communication

In order to maximize the sum-rate of Overlay D2D system, both cellular and D2D users have supposed same goal rates. Several RBs are considered with OFDM system and devised through Binary Linear Programming (BILP) method which is defined as

Maximize:

$$\sum_{n=1}^{N}\sum_{m=1}^{M} \delta_{n,m}^{x} R_{n,m}^{over} \quad (7)$$

Where *x* indicates the *x*th term of RBs. RB allocation index is indicated by binary integer $\delta_{n,m}^{x}$

Subject to:

$$\sum_{n=1}^{N}\sum_{m=1}^{M} \delta_{n,m}^{x} \leq 1, \forall x, \quad (7-a)$$

$$\delta_{n,m}^{x} \in \{0,1\}, \forall (n,m,x)$$

These limitations provide a result that there is only one CUE or DUE per RB. The homogenous interference is mitigated by this limitation.

$$\sum_{x=1}^{X} log_2 \frac{p_{c,n,x|h_{c,n,x}|^2}}{p_{d,m,x|h_{d,m,x}|^2+n_o}} \geq r_c^{over} \quad (7-b)$$

$$\sum_{x=1}^{X} log_2 \frac{p_{d,m,x|h_{d,m,x}|^2}}{p_{c.n,x|h_{c,u,x}|^2+n_o}} \geq r_d^{over} \quad (7-c)$$

Where r_c^{over} and r_d^{over} are minimum rate requirements for CUE and DUE in overlay communication, respectively.

B. Underlay D2D Communication

For underlay, reuse mode is used and it is assumed that there are no dedicated resources available for DUEs or CUEs. In Reuse mode interference between a DUE and CUE plays a vital role in the allocation of resources. DUEs are assumed to work in the same uplink band as CUEs and can reuse RBs of CUEs with least interference. With known channel conditions, BS can assign RBs to certain DUEs by keeping the interference level for CUEs to such extent that it is not harmful for CUEs links. The individual threshold SINRs are set for DUEs and CUEs to keep interference at control level. Uplink transmission throughput as a sum rate in reuse mode can be given by (3): To limit the level of the interference on CUE and DUE, the SINR at both selected DUE and CUE must be higher than some threshold value of SINR.

$$SNR_{c.n} = \geq SINR_{cu}^{th} \qquad \textit{(8-a)}$$

$$SNR_{d,m} = \geq SINR_{du}^{th} \qquad \textit{(8-b)}$$

The problem formulation for reuse mode is same as earlier except the constraint in (7-a) is replaced with (8-a) and (8-b).

5. Simulation and Results

This section estimates the excellence of intended algorithms. The simulations are performed in MATLAB to prove the results. BS is considered as core in a single cell to serve CUEs and DUEs. All nodes are supposed to be familiar with Channel state estimation (CSI). Then, its estimation is done for individual and overall throughput of CUEs and DUEs. Other simulation variables are depicted in Table 1.

Variables	Values
Nominal SNR	20 dB
Available Channel Realization	1000
Channel Scheme	Rayleigh
Available CUEs	3
Available DUE Pairs	3
No. Of RBs	12-72

Table 1. Simulation Variables

Three modes are investigated using simulation in this paper as presented by Figure 2.

1. Reuse mode

In reuse mode, each CUE occupies one resource block and one DUE pair can only reuse resource block of CUE. In this mode D2D networks operate in underlay mode.

2. Dedicated Mode I

In dedicated mode, all resources are equally distributed among all users irrespective of their communication method either in cellular or D2D.

3. Dedicated Mode-II

In dedicated mode II, more resources are allocated to conventional cellular users. In our simulation, we allocate 3/4 resources to CUEs while only 1/4 for D2D users.

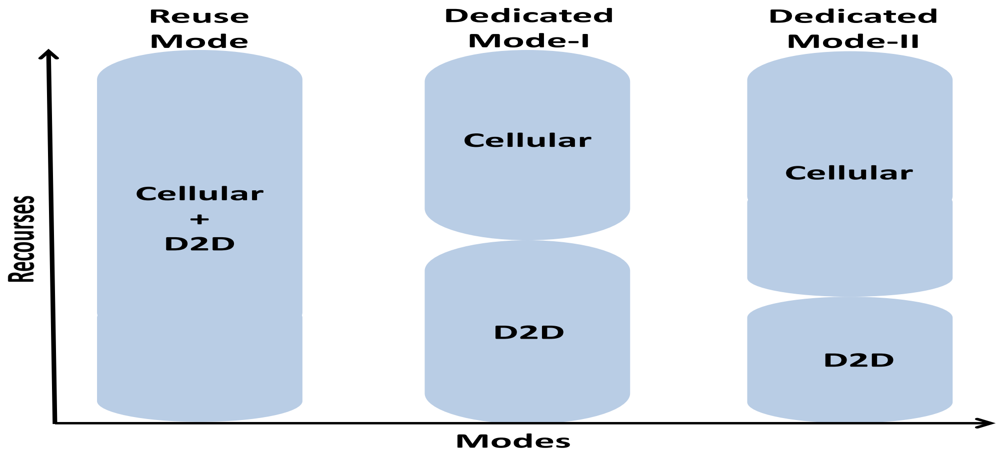
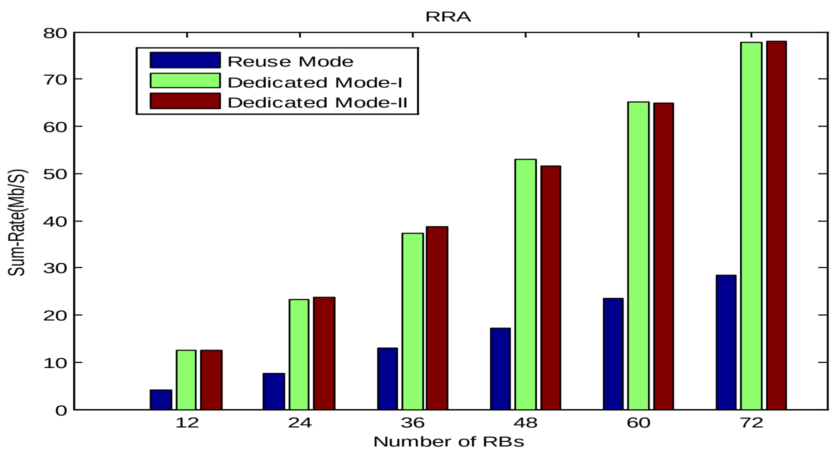
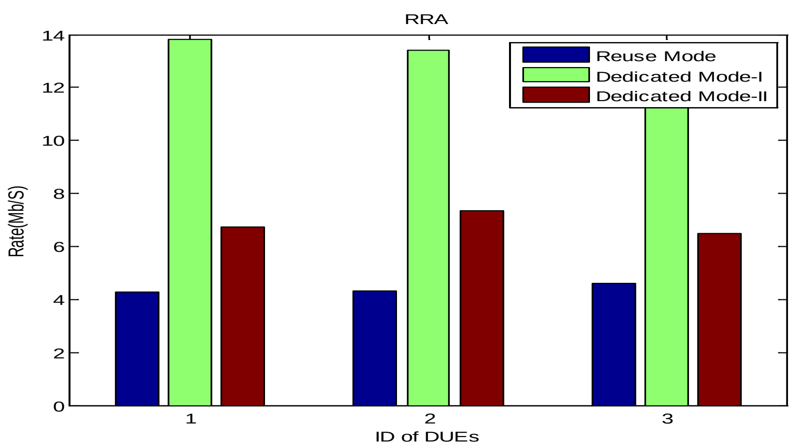


Figure. 2: Resource Allocation Modes

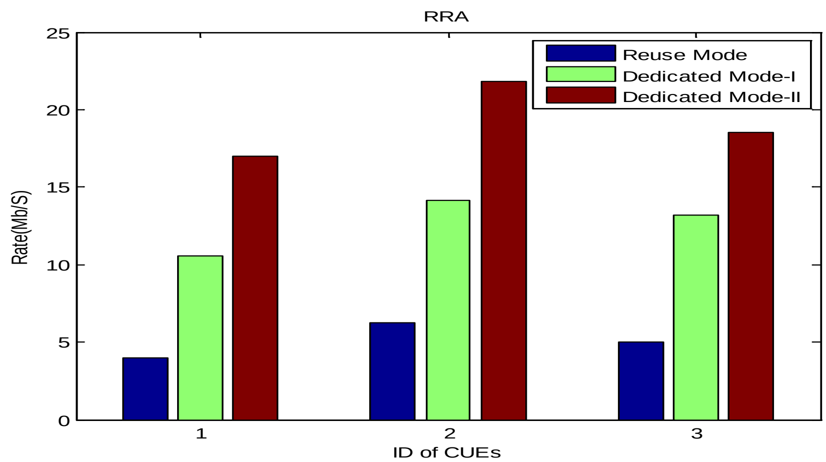
Figure 3, Figure 4 and Figure 5 present the sum-rate of system, individual throughput for DUEs and CUES for three resource allocation algorithms respectively. Figure 3 (a) is depicted between overall throughput and diverse number of given RBs for round robin allocation.



(a)



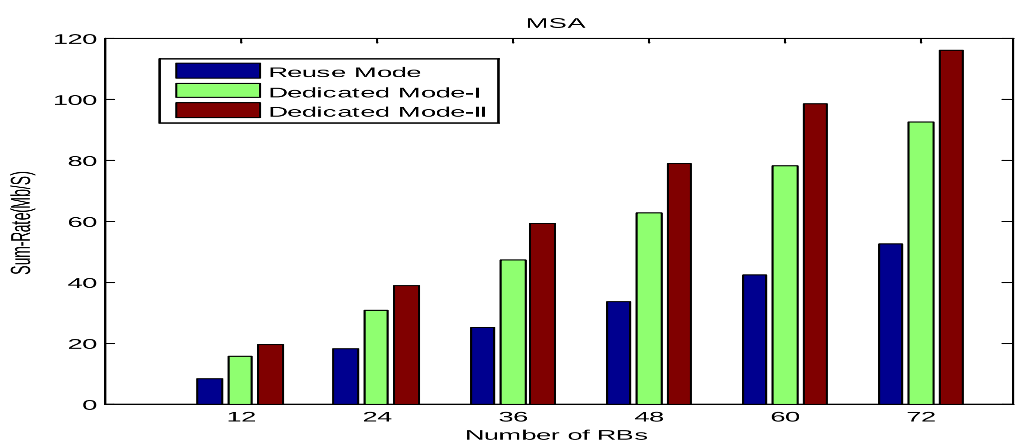
(b)



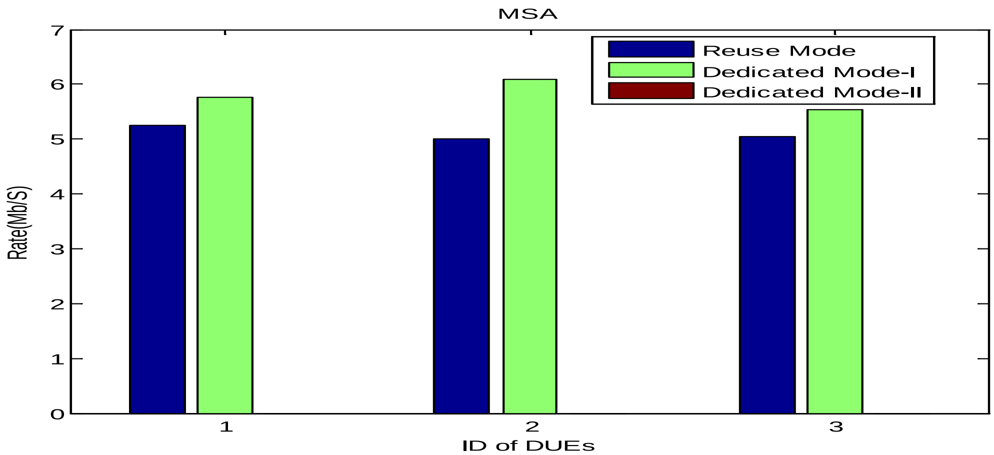
(c)

Figure 3. Round Robin Allocation (a) Throughput of a system versus number of RBs (b) Individual Throughput for Each DUEs (c) Individual Throughput for Each CUE

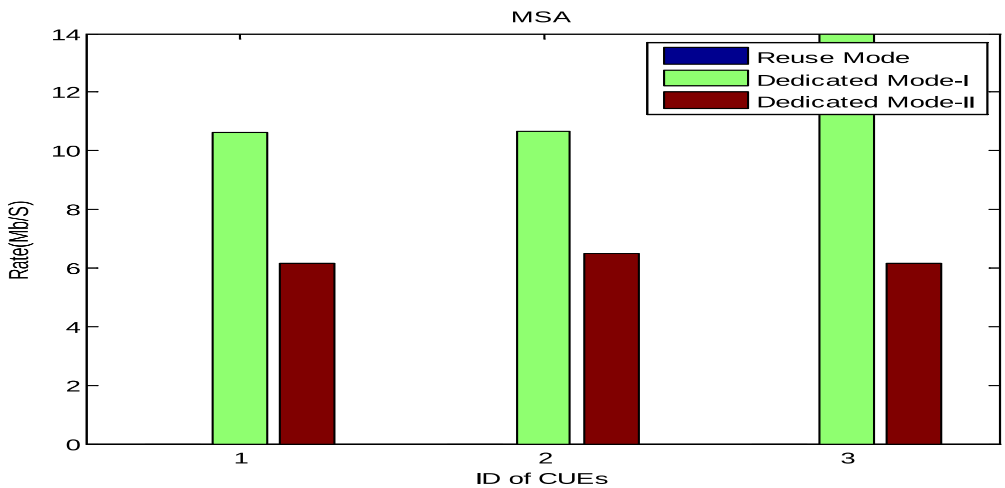
Analysis has shown that Reuse mode has least as compared to overlay modes, this is happening because DUEs are assigned the same channels as CUEs. The same is happening in MSA and PRA methods. The overall sum-rate is enhanced in MSA method but at the same time RPA method also has significant enhancement as compared to RRA method. It can be seen from figure 4(a) and figure 5(a) by comparing with figure 3(a). Even though MSA has highest system throughput as compared to other methods but it lacks in providing fairness among users in terms of data rate. Figure 4 (b) and figure 4(c) are the clear evidence of it, where some DUEs and CUEs are not able to get resources due to bad channel or other condition. On other hand PRA algorithms meets fairness requirements, both CUEs and DUEs can meet this requirement in any scenario and the overall throughput is also enhanced as already shown in Figure 5.



(a)

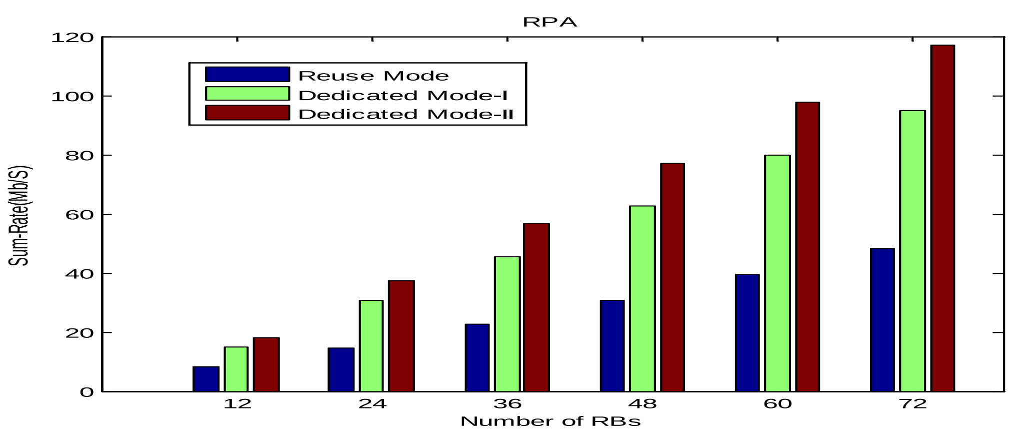


(b)

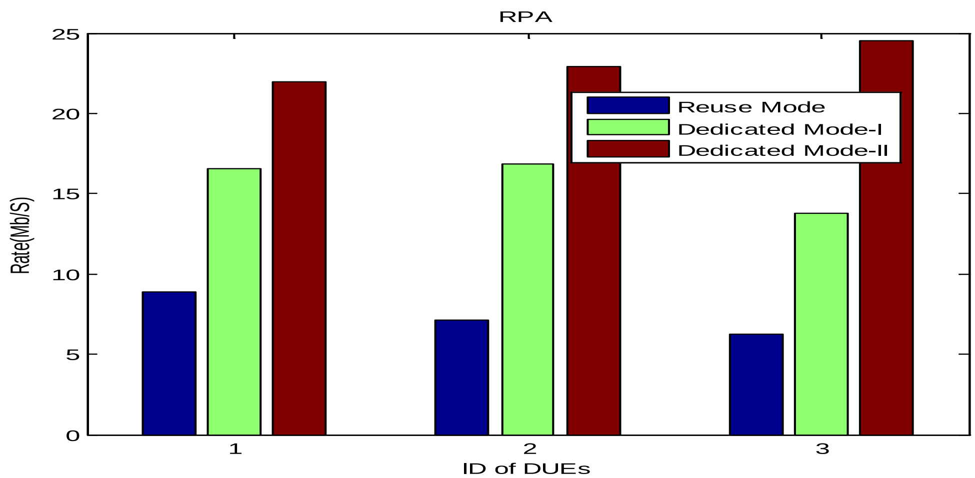


(c)

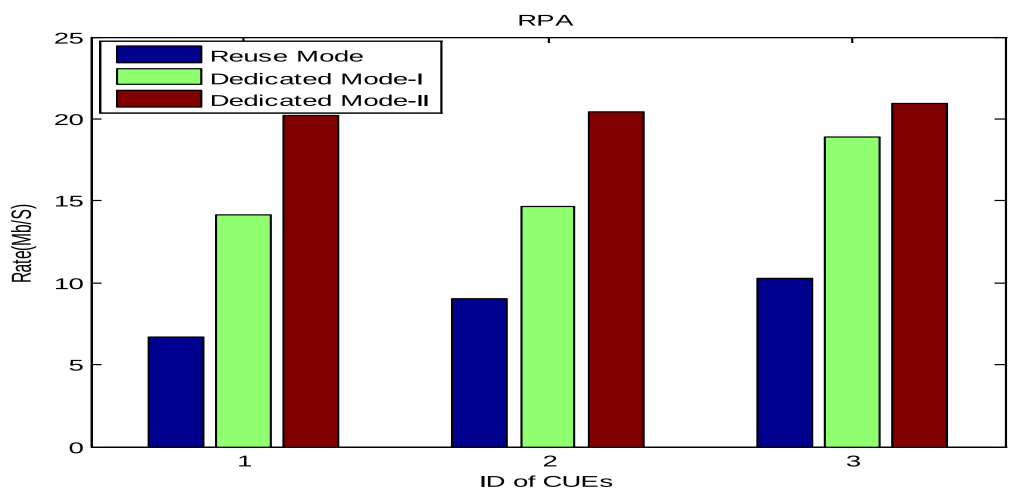
Figure **4:** Maximum SNRs Allocation (a) Throughput of a system versus number of RBs (b) Individual Throughput for Each DUEs (c) Individual Throughput for Each CUE.



(a)



(b)



(c)

Figure 5: Proportional Rate Allocation (a) Throughput of a system versus number of RBs (b)Individual Throughput for Each DUEs (c) Individual Throughput for Each CUE.

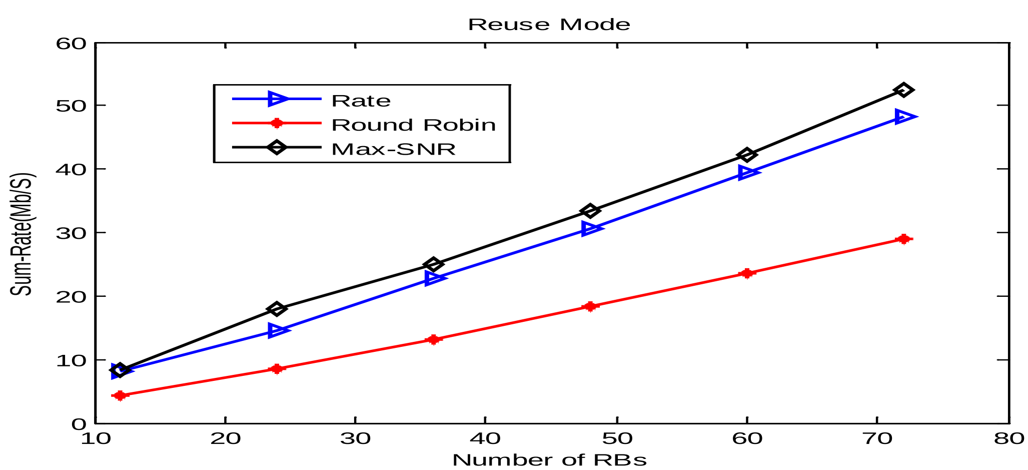


Figure 6: Throughput of a system versus number of RBs in Reuse Mode

Figure 6 shows the comparative analysis of three algorithms in Reuse mode. It can also be seen that the performance of RPA is very near to MSA. But same time it provides all the users with their rate requirements which is indicated in figure 5 (b) and Figure 5(c). The simulation results show nearly optimum throughput when commensurate allocation intended is made in both scenarios i.e. in cellular network overlay D2D communication or cellular network underlay D2D communication.

6. Conclusion:

D2D communication is a key feature of all future technologies. It provides high spatial efficiency and advantageous for catastrophe condition. This paper provides some insight in In-band D2D communication. Resource allocation problem is addressed in both Overlay D2D and underlay D2D. Moreover, the optimization problem for maximum throughput is explored for a Multi-user Cellular system for both D2D systems. A rate proportional resource allocation scheme is analyzed in correspondence with traditional maximum SNR and Round robin allocations. Simulation results verified the increased gain of the rate proportional resource allocation algorithm in terms of proportional fairness between CUEs and DUEs. Simulation results have validated its effectiveness.

Reference:

[1] J. Sun, T. Zhang, X. Liang, Z. Zhang, and Y. Chen, “Uplink Resource Allocation in Interference Limited Area for D2D-Based Underlaying Cellular Networks,” 2016.

[2] S. N. Swain, S. Mishra, and C. S. R. Murthy, “A Novel Spectrum Reuse Scheme for Interference Mitigation in a Dense Overlay D2D Network,” pp. 1201–1205, 2015.

[3] H. E. Elkotby, K. M. F. Elsayed, and M. H. Ismail, “Exploiting interference alignment for sum rate enhancement in D2D-enabled cellular networks,” *IEEE Wirel. Commun. Netw. Conf. WCNC*, pp. 1624–1629, 2012.

[4] Y. Liu and S. Feng, “Interference Pricing for Device-to-Device Communications,” pp. 5239–5244, 2014.

[5] F. Teng, D. Guo, M. L. Honig, W. Xiao, and J. Liu, “Power control based on interference pricing in hybrid D2D and cellular networks,” *2012 IEEE Globecom Work. GC Wkshps 2012*, pp. 676–680, 2012.

[6] T. Kim, S. Lee, and S. Chhorn, “Resource Allocation and Power Control Scheme for Interference Avoidance in LTE-Advanced Device-to- Device Communication,” pp. 1201–1204.

[7] C. Xu, L. Song, Z. Han, Q. Zhao, X. Wang, and B. Jiao, “Interference-aware resource allocation for device-to-device communications as an underlay using sequential second price auction,” *IEEE Int. Conf. Commun.*, pp. 445–449, 2012.

[8] S. H. Kang, J. Kim, and J. G. Kim, “for Cellular based D2D Communication Networks,” no. 2, pp. 1236–1238, 2016.

[9] C.-W. Yeh, G.-Y. Lin, M.-J. Shih, and H.-Y. Wei, “Centralized Interference-Aware Resource Allocation for Device-to-Device Broadcast Communications,” *2014 IEEE Int. Conf. Internet Things(iThings), IEEE Green Comput. Commun. IEEE Cyber, Phys. Soc. Comput.*, pp. 304–307, 2014.

[10] Hyung-sub Kim, Jee-hyeon Na, and Eunsun Cho, “Resource allocation policy to avoid interference between cellular and D2D Links/ and D2D links in mobile networks,” *Int. Conf. Inf. Netw. 2014*, pp. 588–591, 2014.

[11] W. Zhou, X. Sun, C. Ma, J. Yue, H. Yu, and H. Luo, “An interference coordination mechanism based on resource allocation for network controlled Device-to-Device communication,” *2013 IEEE/CIC Int. Conf. Commun. China - Work. CIC/ICCC 2013*, no. Iot, pp. 109–114, 2013.

[12] A. Bhardwaj, “Resource Management for Device-to-Device Multicast in LTE-A Network,” pp. 6–7, 2016.

[13] F. Chiti, D. Di Giacomo, R. Fantacci, and L. Pierucci, “Interference Aware Approach for D2D Communications,” 2016.

[14] Z. Guizani and S. Member, “Spectrum Resource Block Reuse and Power Assignment for D2D Communications Underlay 5G Uplink Network.”