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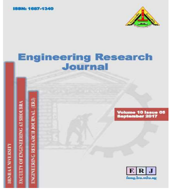

QoS Aware Resource Allocation for D2D Communication in mmWave 5G Underlay Network

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Abstract: Device-to-device (D2D) communication is considered the most promising technology for 5G networks which enables high speed communication in low latency time. D2D communications allows direct links without using central base stations (BSs). Millimeter wave (mmWave) technology is characterized by short distance directive propagation, and more available spectrum for communication. Integrating D2D communication with mmWave technology significantly enhances the system performance and reaches the demand for high capacity. In mmWave D2D communications 5G underlay networks, multiple cellular users (CUs) and D2D users co-exist. Since D2D pairs can utilize the spectrum assigned to CUs, efficient resource allocation algorithms are required. In this paper, a resource allocation problem in mmWave D2D communications 5G underlay network is investigated. A new resource allocation scheme that allows D2D pairs to share resource blocks (RBs) with cellular users is proposed. The proposed scheme prevents congestion on over a few resource blocks while the rest of resource blocks remain vacant through identifying a set of recommended resource blocks for each D2D pairs. The proposed scheme reduces interference by excluding interferer D2D pairs from resource blocks sharing process for each D2D pairs. The proposed scheme maximizes the spectral efficiency while satisfying minimum QoS requirements. The simulation results show the superiority of the proposed scheme in terms of spectral efficiency and outage capacity.

Keywords: D2D communications, mmWave communications, resource allocation, 5G.

1. Introduction

With the increase in the number of devices connected to multimedia networks, the flow of mobile data traffic and the capacity required for mobile communications increase and becomes a major challenge to meet the large bandwidth requirements. Many studies have been conducted to exploit new spectrum bands, including millimeter wave (mmWave), to compensate the scarcity of operational radio frequency resources.

The mmWave is considered as the promising candidate for implementing 5G technology networks to improve the energy efficiency and usage of spectrum. The mmWave network exhibits higher bandwidth in range of 1 GHz and large gigabit data rate due to its small wavelength signals [1-3].

The deploying of D2D communications enables direct communication between proximity user devices without resorting to the central controller Base Stations (BSs), compared with cellular communication. The proximity of D2D users enables reduction of communication latency time, which can achieve lower energy consumption and enhance spectrum efficiency with higher throughput [4–7].

D2D communication technology can also act as relays for edge users who may face weak signal reception to enhance their coverage and throughput [8, 9]. The combination of D2D communication and mmWave has some major merits such as realizing higher system capacity, implementing high bandwidth intensive applications, and achieving higher energy efficiency. In practical situations, the battery is limited, so the energy conservation should be considered in D2D networks design [10].

The mmWave communication in indoor network is more vulnerable to lose a lot of signal strength because of signal blockage by interception from buildings, trees, and walls. This shortcoming is considered one of the most important challenges for successful D2D communication in mmWave transmission band. The biggest challenge facing D2D communication networks lies in the complex interference with the cellular networks, since the D2D users need to share the same resources with cellular users in uplink spectrum [11].

The D2D communications serves as the underlay for cellular networks, and by reusing the same resources as the cellular users; the level of interference can be further amplified. Resource allocation can counter this problem and mitigate the effect of interferences [12, 13]. Therefore, to reap the benefits of D2D communication, it is required to have effective techniques for resource allocation to facilitate proper operation of cellular users along with D2D communication networks.

The resource allocation elements include power allocation, mode selection, relay control, delay control, interference control algorithms, and spectrum allocation. Most of these elements are developed to achieve higher throughput, maximum capacity rate, higher spectrum efficiency, lower energy consumption, and optimum quality of service (QoS) for both D2D user pairs and cellular users [14].

In this paper, a new resource allocation scheme for mmWave D2D communications in mmWave underlay 5G networks is proposed. The proposed scheme allows D2D pairs to share resources with cellular users. The proposed scheme maximizes spectral efficiency while taking QoS requirements into consideration. The simulation results show the superiority of the proposed scheme in terms of spectral efficiency and outage probability.

This paper is organized as follows: Section two discusses the related work. The proposed system model is presented in section three. Section four discusses the problem description and formulation. The detailed design of the proposed QoS aware resource allocation scheme is presented in section five. Section six presents simulation experiments results and discussion. Finally, the paper conclusion is presented in section seven.

2. Related Work

Recently,considerable works have been focused on different aspects of D2D communications. An optimization problem of D2D communication spectrum resource allocation is formulated in [15] among micro-wave and mm-wave bands in Heterogeneous cellular networks (HCNs), considering complex intra- and inter-cell interferences. The authors in [15] propose a heuristic algorithm to maximize the system transmission rate and minimize the interference using the advantages of mmwave and cellular networks. The uplink resource allocation problem is investigated for D2D communications.

The work in [16] visualizes combined resource allocation and beamforming design for multi-user mmWave mobile edge computing (MEC) systems. The maximum system delay is minimized by optimizing the analog and digital beamforming matrices at the users and base station, while considering resource allocation and task offloading ratios computation at the MEC server. The optimization problem is introduced as nonconvex and solved by the penalty dual decomposition technique.

The authors in [17] derive power allocation and optimal link selection scheme for backhaul and mmWave Pico cellular networks, considering the effect of interference. They use two nested simulated-annealing algorithms to address the transmitter selection and power allocation problems. Their proposed model can support beamforming and MIMO schemes at physical layer.

A framework is proposed in [18] to optimize the resource allocation in mmWave-NOMA communication for crowded venues considering the effect of blockage caused by obstacles. The network sum rate is maximized by formulating the resource allocation as mixed-integer non-linear programming problem. The quality-of-service constraints is guaranteed for the system by solving non-convex power allocation optimization problem using the difference of programming convex approach.

In [19], an optimal resource allocation problem for downlink coverage from mmWave transmitter on an unmanned aerial vehicle (UAV) is investigated. The circular user space is divided into multiple sectors considering directional beam produced by the antenna array. The signal-to interference-plus-noise ratio expression is derived according to concurrent transmissions in different sectors. The resource allocation problem is optimized as a mixed-integer non-convex programming to maximize the sum rate while ensuring minimum rate guarantee to each user.

The authors in [20] propose the geometry programing method of power allocation. After the power is allocated the authors proposed a Hungarian algorithm for resource blocks allocation. In [21], the authors design an efficient energy mobile-edge computation offloading algorithm in an ultra-dense Internet of Things to analyze the tradeoff between energy consumption and the system execution delay. The optimal power allocation and computation offloading are realized using an iterative algorithm with the successive convex approximation approach.

In [22], an effective allocation approach using many-to-one Gale-Shapley algorithm is proposed to solve interference and spectrum optimization problem caused by D2D users multiplexed cellular network users in heterogeneous cellular networks. The total capacity of D2D users is maximized by matching cellular channel and D2D clusters based on Kuhn–Munkres algorithm. The authors in [23] formulate energy-aware scheme to optimize the energy efficiency and the achievable sum rate for cellular user while minimizing the input power constrains and QoS requirements. They analyze the tradeoff between outage probability and sum rate at various QoS levels, considering cellular users' density, to maximize energy efficiency.

The solution of battery limited capacity is offered in [24] by introducing a relay-enabled mmWave D2D communication to minimize the transmit power and maximize system throughput. The authors formulate an optimization function to achieve minimum data rate and relay aggregate transmission power D2D constrains. The authors in [25] consider a resource allocation to maximize the efficiency of the outdoor mmWave D2D underlay network system spectrum, while distributing the resources fairly inside a cell. The optimal resource allocation is guaranteed by formulating sum rate maximization problem to improve system throughput and increase the spectrum efficiency.

The resource allocation process is optimized in [26] by considering an E-band urban area D2D undelay millimeter-wave network to improve throughput and spectrum efficiency. The authors solve the resource allocation optimization function by introducing a heuristic algorithm in an outdoor realistic path loss to reduce interference in a dense network and offer overall system throughput. The authors in [27] propose an uplink resource allocation nonlinear optimization function for mmWave and microwave band users to maximize the system sum rate by applying a coalition formation game.

3. System Model

In this work, a single cell 5G cellular networks Employing D2D communication is considered, where the base station (BS) is placed at the center of the cell. The system includes M cellular users and D D2D pairs operating in the same cell. The BS has a set of K resource blocks (RBs), each of which has an available bandwidth B. In this work an uplink transmission of a single cell is considered. The system model is shown in Figure 1.

To reduce interference, it is assumed that D2D pairs can share the RBs of only one cellular user, while cellular users can share their RBs to many D2D pairs as their channel status allows. Two binary variables ε_{md} and $\rho_{dd'}$ are defined such that ε_{md}=1 if D2D pair d shares RB with cellular user m, and ε_{md}=0 otherwise, while $\rho_{dd'}$=1 if D2D pair d shares RB with D2D pair d' and $\rho_{dd'}$=0 otherwise.

The signal received at BS receiver is given by:

$$y_B = \sqrt{P_{mk}} h_{mB} x_{mk} +$$

$$\sum_{d=1}^{D} \varepsilon_{md} \sqrt{P_{dk}} h_{dB} x_{dk} + N_n$$

The signal received at D2D receiver is given by:

$$y_d = \sqrt{P_{dk}}\, h_{dd}\, x_{dk} + \sum_{m=1}^{M} \varepsilon_{md} \sqrt{P_{mk}} h_{md} x_{ck} + \sum_{d'=1}^{D} \rho_{dd} \sqrt{p_{d'k}}\, h_{d'd}\, x_{d'k} + N_n \quad (1)$$

Where:

h_{mB} is the channel gain for the link between cellular user m TX and BS RX, h_{dB} is the channel gain for the link between D2D TX and BS RX, h_{md} is the channel gain for the link between cellular user m TX and D2D RX, h_{dd} is the channel gain for the link between devices in D2D pair, $h_{d'd}$ is the channel gain between one D2D pair TX and another D2D pair RX, P_{dk} and P_{mk} are the transmit power of D2D pairs *d*, and cellular user m respectively, considering the RB k, and N_n is the AWGN noise in the channel.

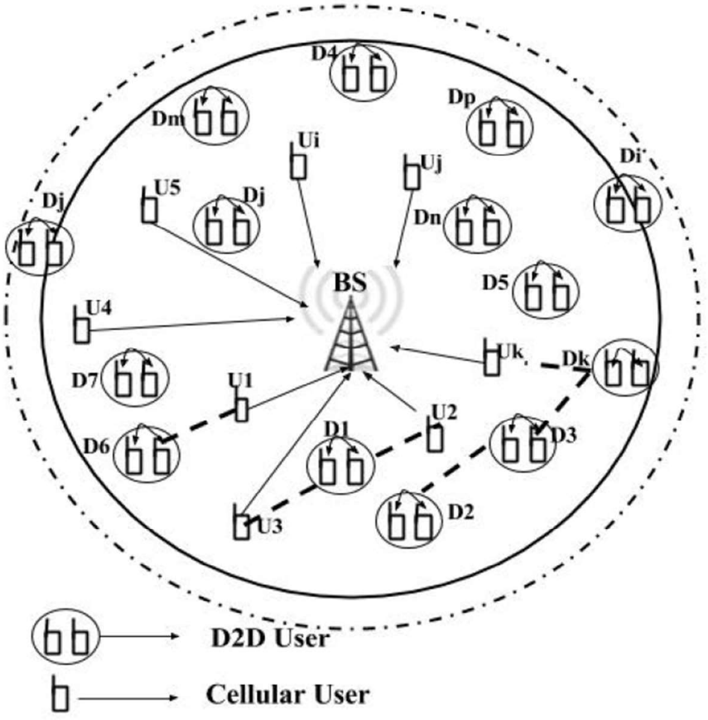

Figure 1 System model [25]

Bands in the millimeter wave are typically ranged from 28, 38, 60, 71-76, and 81-86 GHz respectively [20]. In this work, the mmWave band is assumed 28 GHz. The path loss (PL) model has two components, the Line of sight (LOS), and the non-line of sight (NLOS) components. Each of them is associated with the corresponding shadowing. The PL is calculated as :

$$PL = PL_{LOS} + PL_{NLOS}$$
$$PL_z = \xi + 10\upsilon \log d + \chi$$

where

z is LOS, or NLOS

χ is ~N(0,σ_χ^2)

ξ is the PL coefficient, ν is its exponent, and χ is its corresponding lognormal shadowing with a mean of zero, and a variance $of\ \sigma_\chi^2$.

Two probabilities p_1 , and p_2 are added to the lognormal path-loss and shadowing model. It is considered that D2D receives more LOS signals given their proximity. The D2D link PL is calculated as in [28]:

$$PL = p_1 PL_{LOS} + (1 - p_1) PL_{NLOS}$$

For the other links, (BS-D2D), (D2D-CU) or (CU-CU) and (CU-BS), the PL is expressed as follows:

$$PL = p_2 PL_{LOS} + (1 - p_2) PL_{NLOS}$$

The signal to interference and noise ratio at D2D pair Rx γ_d, and the signals to interference and noise ratio corresponding to CU γ_m are given by

$$\gamma_d = \frac{\sqrt{P_{dk}}\; h_{dd}\, x_{dk}}{\sum_{m=1}^{M} \varepsilon_{md} \sqrt{P_{mk}} h_{md} x_{ck} \; + \sum_{d\prime=1}^{D} \rho_{dd} \; \sqrt{p_{d\prime k}}\, h_{d\prime d}\, x_{d\prime k} + N_n}$$

$$\gamma_m = \frac{\sqrt{}P_{mk} h_{mB} x_{mk}}{\sum_{d=1}^{D} \varepsilon_{md} \sqrt{P_{dk}} h_{dB} x_{dk} \; + \; N_n}$$

It is assumed that there exist predefined threshold values for the signal to interference and noise ratios at D2D pair Rx γ_{dt} , and corresponding to CU γ_{mt} such that $\gamma_d, and\ \gamma_m$ must satisfy:

$$\gamma_d > \gamma_{dth}$$

$$\gamma_m > \gamma_{mth}$$

The minimum accepted rate for CU, and D2D pairs are given by [28]:

$$R_{m\_min} = B\,\log(1 + \left(\frac{-1.5}{\ln(5BER_m)}\,\gamma_{mth}\right))$$

$$R_{d\_min} = B\,\log(1 + \left(\frac{-1.5}{\ln(5BER_d)}\,\gamma_{dth}\right))$$

4. Problem description and formulation:

The data rates for cellular user *m* R_m , and data rate of D2D *d* R_d are given by

$$R_m = B\,\log(1 + \left(\frac{-1.5}{\ln(5BER_m)}\,\gamma_m\right))$$

$$R_d = B\,\log(1 + \left(\frac{-1.5}{\ln(5B\quad d)}\,\gamma_d\right))$$

R_T is the total achieved rate and is given by:

$$R_T = (\sum_{m=1}^{M} R_m + \sum_{d=1}^{D} R_d\,)$$

The spectral efficiency is defined as

$$U = \frac{R_T}{B}$$

The optimization problem is described by

$$\max_{\varepsilon}(\,U)$$

subjected to

$$\gamma_d > \gamma_{dth}$$

$$\gamma_m > \gamma_{mth}$$

$$P_d < P_{dmax}$$

$$P_m < P_{mmax}$$

$$\sum_{m=1}^{M} \varepsilon_{md} = 1 \ \forall d$$

5. Proposed QoS aware resource allocation scheme

The proposed scheme is a two steps algorithm:

5.1 Step 1: Power allocation

To maximize the sum rate of both the D2D and cellular users, the allocation of power to D2D devices is achieved using iterative water-filling method [29].

5.2 Step 2: Resource allocation:

Before allocation of resource blocks, the proposed scheme identifies for each D2D pairs two important sets. These two sets are the set of interferers D2D pairs for each resource block k , Ω_{dk}, and the set of recommended resource blocks RBs to share with cellular users, Ψ_d . these sets are identifying as follow:

- identify the set of interferers of each D2D pairs for each resource block k , Ω_{dk}

For each D2D pairs identify the set of interferers on subcarriers k Ω_{dk} , given the predefined interference threshold η_{th}

$$\Omega_{dk} = \{ j \in D,\ j \neq d \,|\, P_{jk} h_{jd} > \eta_{th} \}$$

To eliminate interference resulting from more than D2D pairs using the same resource block k, interfering D2D pairs are not allowed to share the same RB

For each D2D pairs d

if $d' \in \Omega_{dk}$ set $\rho_{dd'} = 0$

- identify the set of recommended RBs to share with cellular users for each D2D pairs, Ψ_d :

In this step, since all users are expected to achieve a certain minimum of data rate, given by $R_{\min}$, the proposed scheme identify the set of recommended resource blocks the cellular user shares with D2D pairs, while maintaining the minimum rate constrains for both cellular user and D2D pairs. The set Ψ_d is the set of resource blocks. The minimum rate is maintained for cellular users, and D2D pairs if

$$(R_{dK} - R_{d\_min}) > 0 \ and \ (R_{mk} - R_{m_{\min}}) > 0$$

The proposed scheme allocates RBs to D2D pairs to share with cellular users such that the system spectral efficiency is maximized. Since maximizing system total sum rate directly maximize system spectral efficiency, the proposed scheme allocates resource block k^* for D2D pairs *d*, such that:

$$k^* = \arg\max_k (R_{Tk}) \quad , k^* \in \Psi_d$$

```
Algorithm 1 proposed scheme
Step 1: power allocation
Step 2: Resource allocation:
    i)Avoid sharing of RBs with interferers D2D pairs
        for each D2D pairs within the cell coverage area
            define the set of interfering D2D pairs $\Omega_{dk}$ for each RB k, $1 < k < K$
                $\forall d' = 1,2..,D; d' \neq d$
                    if $d' \in \Omega_{dk}$
                    then $\rho_{dd'} = 0$
                    end if
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        end for
      ii) based on QoS requirements, identify $\Omega_d$ ,the set of recommended RBs to share with
        CUs for each D2D pairs
  For $d = 1$ to $D$
      FOR k= 1 TO K
          If $(R_{mk} - R_{m\_min})$ and $(R_{dK} - R_{d\_min})$ > 0
          K is added to $\Omega_d$
          End if
    End for
  End for
  iii) Given the set of recommended RBs, select RB k* that maximizes system total sum rates
        Select RB $k^* \epsilon \Omega_d$ such that $R_{Tk*}$ is maximized
        $k^* = \arg\max_{k} (R_{Tk}) \ , k^* \epsilon \Omega_d$`
```

6. Simulation Results and discussions

In this section, the performance of the proposed scheme is assessed in terms of spectral efficiency U, and outage probability P_O . where P_O is the probability of SINR falls below the predefined SINR threshold. The outage probability is expressed as $P_O = prob\{\gamma_d < \gamma_{th}\}$

A simulation is implemented through MATLAB R2015b to evaluate the efficiency of the proposed scheme. In the simulation, it is assumed that the cellular users and D2D pairs are uniformly distributed within the coverage area of the cell. The simulation parameters are summarized in table 1.

Table 1 simulation parameters

Parameter	**Value**
Cell radius	500m
$f\_\mu m$	28GHz
$B\_\mu m$	1GHz
BW of resource block	*180 kHz*
Path loss probability for D2D links	$p_1 = 0.8$
Path loss probability for no D2D links	$p_2 = 0.2$
Path Loss LOS $(\xi, \upsilon, \sigma_x)$	(61.4,2,5.8 dB)
Path Loss N-LOS $(\xi, \upsilon, \sigma_x)$	(72,2.92,8.7 dB)
Noise power density	-174 dBm/Hz
SINR threshold for CU	0 dB
SINR threshold for DU	0 dB
Maximum device transmit power	23dBm
Interference threshold η_{th}	-7dB

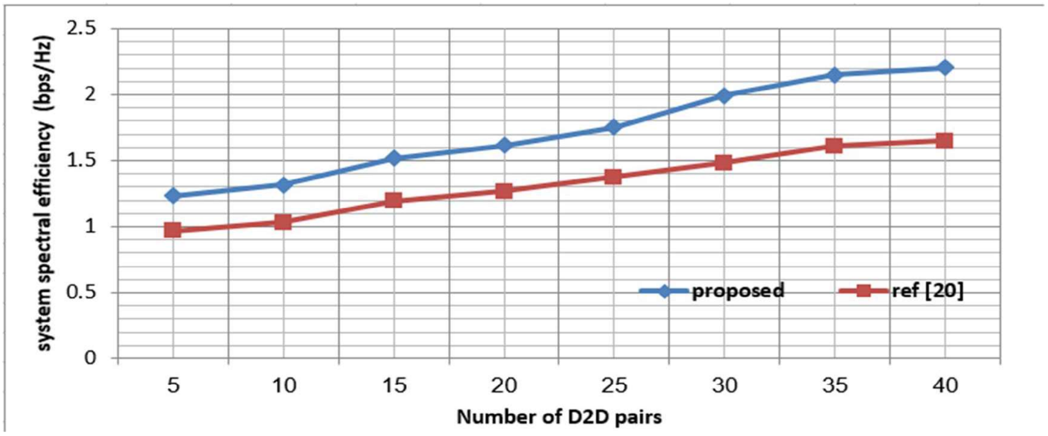

Figure 2 System spectral efficiency for different number of D2D pairs

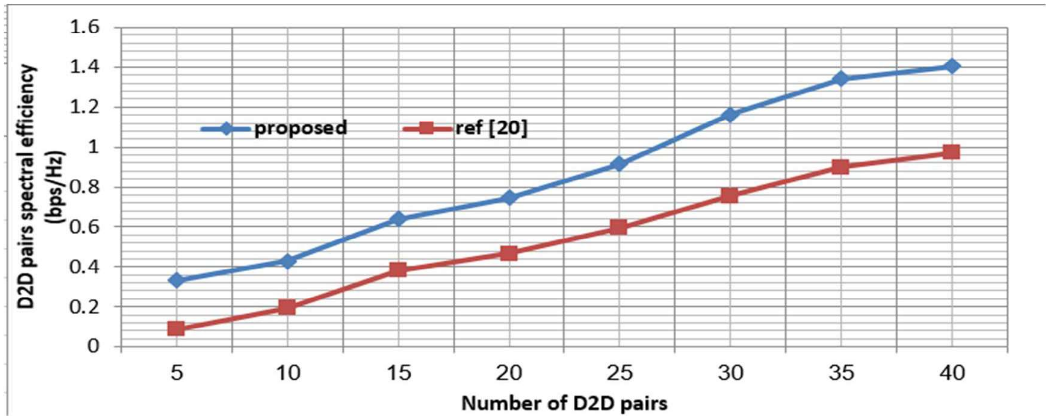

Figure 3 D2D pairs spectral efficiency for different number of D2D pairs

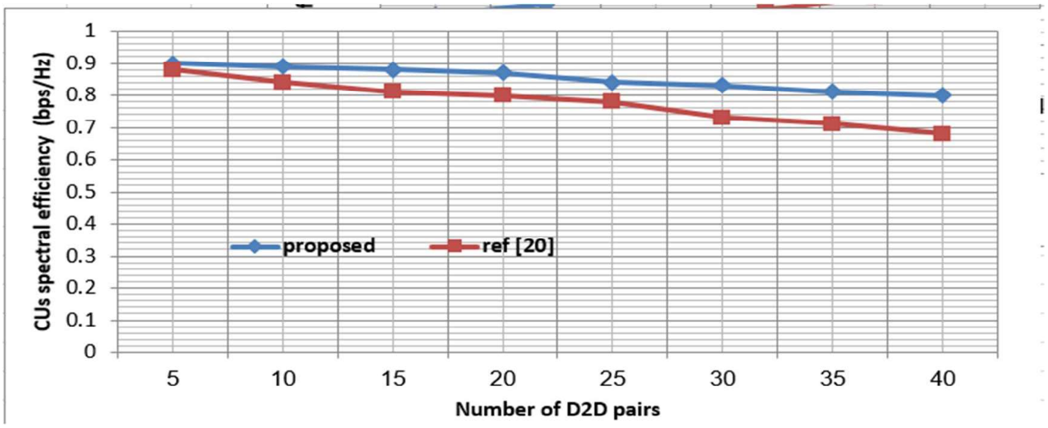

Figure 4 D2D pairs spectral efficiency for different number of D2D pairs

In Figures 2-4, the spectral efficiency is studied for different numbers of D2D pairs, which are trying to share the RBs with cellular users in the system. It can be deduced from Figures 2 and 3 that the proposed scheme improves both system spectral efficiency and D2D pairs spectral efficiency for different number of D2D pairs.

The relative improvement in the spectral efficiency with increasing number of D2D pairs in the proposed scheme is a result of the constrains which the proposed scheme put on sharing RBs with interfering D2D pairs. As shown in Figure 2, the spectral efficiency improvement continues, even for large number of D2D pairs. Comparing the gain in spectrum efficiency with that of [20], the gain in spectrum efficiency for [20] decreases with the increase in the number of D2D pairs, which is realized as the increase in the interference from neighboring D2D pairs. Whereas, for the proposed scheme, the gain in spectral efficiency exists even with the increasing number of D2D pairs.

In Figure 4, the effect of sharing D2D pairs the RBs with Cellular users on the spectrum efficiency of cellular users is studied. As shown in Figure 4, the proposed scheme is an effective solution to reduce the degradation in cellular users' spectral efficiency with increasing the number of D2D pairs. The degradation in spectral efficiency as the number of D2D increase from 5 to 40 is only 11%, while it is 22% in [20].

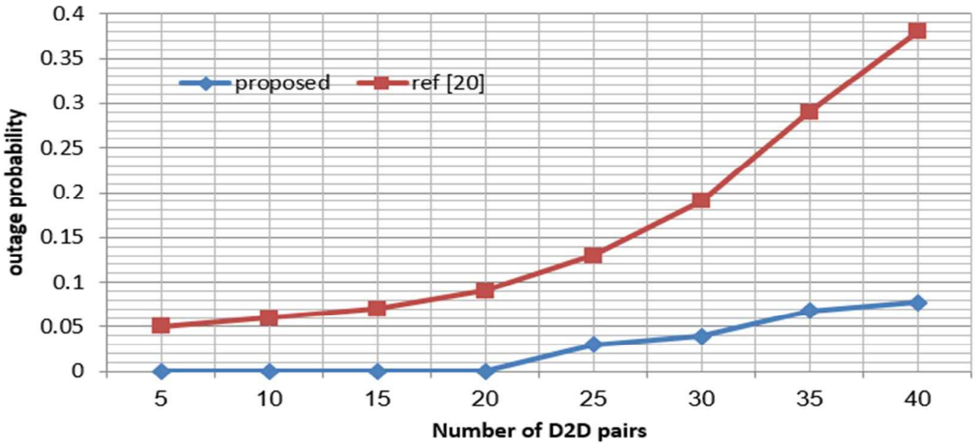

Figure 5 outage probability for different number of D2D pairs

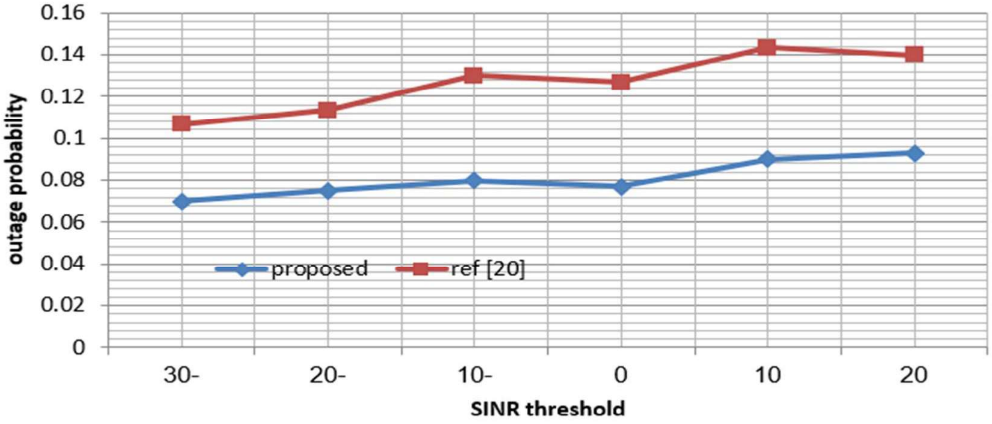

Figure 6 outage probability for different SINR threshold values

In Figures 5, and 6, the outage probability is studied. Figure 5 deduces that as the number of D2D pairs increases, the proposed scheme achieves better outage probability than [20]. With increasing the number of D2D pairs, the gap in the performance between the proposed scheme and [20] increases. Form Figure 5, it can be deduced that the proposed scheme is able to keep an acceptable outage probability level even with high numbers of D2D pairs. Figure 6 shows that the proposed scheme achieves better outage probability for different values of SINR threshold.

7. Conclusions

In this paper, resource allocation for D2D Communication in mmWave 5G Underlay Network is studied. A new resource allocation scheme is proposed. The proposed scheme starts with allocating power, and then allocating resource blocks. The proposed scheme maximizes the spectral efficiency while guaranteeing the minimum QoS requirements. Simulation results indicate that the proposed scheme shows performance improvement in spectral efficiency and outage probability compared to [20].

References

[1] A. Gupta and R. K. Jha, "A Survey of 5G Network: Architecture and Emerging Technologies," IEEE Access, vol. 3, pp. 1206–1232, 2015, doi: 10.1109/ACCESS.2015.2461602.

[2] H. Alsaif, "Extreme Wide Band MIMO Antenna System for Fifth Generation Wireless Systems," Engineering, Technology & Applied Science Research, vol. 10, no. 2, pp. 5492–5495, Apr. 2020.

[3] F. O. Ombongi, H. O. Absaloms, and P. L. Kibet, "Resource Allocation in Millimeter-Wave Device-to-Device Networks," Mobile Information Systems, vol. 2019, Dec. 2019, doi: https://doi.org/10.1155/2019/5051360, Art no. 5051360.

[4] F. Jameel, Z. Hamid, F. Jabeen, S. Zeadally, and M. A. Javed, "A Survey of Device-to-Device Communications: Research Issues and Challenges," IEEE Communications Surveys & Tutorials, vol. 20, no. 3, pp. 2133–2168, 2018.

[5] C.-L. I. S. Han, and S. Bian, "Energy-efficient 5G for a greener future," Nature Electronics, vol. 3, pp. 182–184, Apr. 2020, doi:10.1038/s41928-020-0404-1.

[6] Lee,W.; Ban, T.W.; and Jung, B.C. "Distributed Transmit Power Optimization for Device-to-Device Communications Underlying Cellular Networks", IEEE Access 2019, 7, 87617–87633.

[7] J. J. Liu, N. Kato, J. F. Ma, and N. Kadowaki, "Device-to-Device Communication in LTE-Advanced Networks: A Survey," IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 1923–1940, Dec. 2014.

[8] J. Liu, S. Zhang, N. Kato, H. Ujikawa, and K. Suzuki, "Deviceto-device communications for enhancing quality of experience in software defined multi-tier LTE-A networks," IEEE Network, vol. 29, no. 4, pp. 46–52, 2015.

[9] L. Wei, R. Q. Hu, Y. Qian, and G. Wu, "Key elements to enable millimeter wave communications for 5G wireless systems," IEEE Wireless Communications, vol. 21, no. 6, pp. 136–143, 2014.

[10] J. J. Liu, Y. C. Kawamoto, H. Nishiyama, N. Kato, and N. Kadowaki, "Device-to-device communications achieve efficient load balancing in LTE-advanced networks," IEEE Wireless Communications, vol. 21, no. 2, pp. 57–65, Apr. 2014.

[11] Shamaei, S.; Bayat, S.; and Hemmatyar, A.M.A. "Interference Management in D2D-Enabled Heterogeneous Cellular Networks Using Matching Theory", IEEE Trans. Mob. Comput. 2019, 18, 2091–2102.

[12] Lee,W.; Ban, T.W.; and Jung, B.C. "Distributed Transmit Power Optimization for Device-to-Device Communications Underlying Cellular Networks", IEEE Access **2019**, 7, 87617–87633.

[13] Wang, F.; Li, Y.; Wang, Z.; Yang, Z. "Social-community-aware resource allocation for D2D communication underlying cellular networks", IEEE Trans. Veh. Technol. **2016**, 65, 3628–3640.

[14] Ma, R.; Xia, N.; Chen, H.H.; Chiu, C.Y.; Yang, C.S. "Mode selection radio resource allocation, and power coordination in D2D communications", IEEE Wirel. Commun. **2017**, 24, 112–121.

[15] Y. Chen, B. Ai, Y. Niu, R. He, Z. Zhong and Z. Han, "Resource Allocation for Device-to-Device Communications in Multi-Cell Multi-Band Heterogeneous Cellular Networks," in IEEE Transactions on Vehicular Technology, vol. 68, no. 5, pp. 4760-4773, May 2019, doi: 10.1109/TVT.2019.2903858.

[16] C. Zhao, Y. Cai, A. Liu, M. Zhao and L. Hanzo, "Mobile Edge Computing Meets mmWave Communications: Joint Beamforming and Resource Allocation for System Delay Minimization," in IEEE Transactions on Wireless Communications, vol. 19, no. 4, pp. 2382-2396, April 2020, doi: 10.1109/TWC.2020.2964543.

[17] F. Gómez-Cuba and M. Zorzi, "Twice Simulated Annealing Resource Allocation for mmWave Multi-hop Networks with Interference.," ICC 2020 - 2020 IEEE International Conference on Communications (ICC), Dublin, Ireland, 2020, pp. 1-7, doi: 10.1109/ICC40277.2020.9149128.

[18] F. Barghikar, F. S. Tabataba and M. N. Soorki, "Resource Allocation for mmWave-NOMA Communication through Multiple Access Points Considering Human Blockages," in IEEE Transactions on Communications, 2020, doi: 10.1109/TCOMM.2020.3045788.

[19] S. Kumar, S. Suman and S. De, "Dynamic Resource Allocation in UAV-enabled mmWave Communication Networks," in IEEE Internet of Things Journal, 2020, doi: 10.1109/JIOT.2020.3027476.

[20] Job MochengoKerosi, Heywood OumaAbsaloms, and Philip Kibet Langat, "Resource Allocation For Device-To-Device Communication In Millimeter Wave Underlay Network", INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH, Vol. 8, ISSUE 09, pp. 1653- 1660, 2019.

[21] N. Nouri, J. Abouei, M. Jaseemuddin and A. Anpalagan, "Joint Access and Resource Allocation in Ultradense mmWave NOMA Networks With Mobile Edge Computing," in IEEE Internet of Things Journal, vol. 7, no. 2, pp. 1531-1547, Feb. 2020, doi: 10.1109/JIOT.2019.2956409.

[22] Omar A. Saraereh, Saleem Latteef Mohammed, Imran Khan, Khaled Rabie, and Sofeine Affess, "An Efficient Resource Allocation Algorithm for Device-To-Device Communications", Applied Sciences. **2019**, 9, 3816; doi:10.3390/app9183816.

[23] S. A. R. Naqvi, H. Pervaiz, S. A. Hassan et al., "Energy-aware radio resource management in D2D-enabled multi-tier HetNets," IEEE Access, vol. 6, pp. 16610–16622, 2018.

[24] B. Ma, H. Shah-Mansouri, and V. Wong, "Full duplex relaying for D2D communication in mmWave based 5G networks," IEEE Transactions on Communications, vol. 177, pp. 4417–4431, 2018.

[25] G. D. Swetha and G. R. Murthy, "Fair resource allocation for D2D communication in mmWave 5G networks," in Proceedings of the 16th Annual Mediterranean Ad Hoc Networking Workshop, Med-Hoc-Net 2017, Budva, Montenegro, June 2017.

[26] Z. Guizani and N. Hamdi, "Mmwave E-band D2D communications for 5G underlay networks: effect of power allocation on D2D and cellular users throughputs," in Proceedings of the IEEE Symposium on Computers and Communication (ISCC), Messina, Italy, June 2016.

[27] Y. Chen, B. Ai, Y. Niu, and K. Guan, "Resource allocation for device-to-device communications underlaying heterogeneous cellular networks using coalitional games," IEEE Transactions on Wireless Communications, vol. 17, no. 6, pp. 4163–4176, 2018.

[28] Z. Guizani and N. Hamdi, "Spectrum resource management and interference mitigation for D2D communications with awareness of BER constraint in mmWave 5G underlay network," 2016 IEEE Symposium on Computers and Communication (ISCC), Messina, Italy, 2016, pp. 855-860, doi: 10.1109/ISCC.2016.7543843.

[29] W. Yu, W. Rhee, S. Boyd, and J. M. Cioffi, "Iterative water-filling for gaussian vector multiple-access channels," IEEE Transactions on Information Theory, vol. 50, no. 1, pp. 145–152, 2004.