Menoufia J. of Electronic Engineering Research (MJEER), Vol. 31 , No. 2, 2022

D2D communication with Radio resources scheduling in 5G Millimeter wave Heterogeneous Networks

Ahmed. A. Rosas*
Dept. of Electronics and Electrical Communication Engineering
Faculty of Electronic Engineering
Menoufia University
Menoufia, Egypt
ahmed.ali30@el-eng.menofia.edu.eg

Mona Shokair
Dept. of Electronics and Electrical Communication Engineering
Faculty of Electronic Engineering
Menoufia University
Menoufia, Egypt City
shokair_1999@hotmail.com

M.I. Dessouky
Dept. of Electronics and Electrical Communication Engineering
Faculty of Electronic Engineering
Menoufia University
Menoufia, Egypt
dr_moawad@yahoo.com

Abstract— **Due to the explosive growth in the density of wireless network services, applications, and technologies, optimal power consumption and radio resource management with interference mitigation can be emerged as a critical issues for future fifth-generation (5G) heterogeneous networks (HetNets). Millimeter Wave (mm-wave) technology with small cells implemented in heterogeneous 5G networks is deployed as a practical solution to deal with diverse network infrastructures, massively linked devices, and services with multi-gigabit access data rates. In this paper, we propose a jointly optimal power and concurrent radio resource transmission schedule for radio access, backhaul (BH) and Device to Device (D2D) communication links in heterogeneous 5G mmWave networks. Furthermore, for both Line Of Sight (LOS) and Non Line Of Sight (NLOS) transmission, the scheme allows different interfering and non-interfering links to transmit concurrently. Finally, Comprehensive simulations demonstrate that the proposed scheme can achieves significant improvement in terms of radio resources utilization and average user throughput.**

Keywords—heterogeneous network, millimeter wave, D2D communication, backhauling, genetic algorithm

I. INTRODUCTION

Due to the increased density of small-cell networks with different infrastructures and radio access technologies [1], heterogeneous 5G cellular networks [2] is usually referred to fulfill such these challenges. Using mmWave [3]-[4] technology with a small cells in 5G HetNets is considered as a promising candidates to provide a growing attention in overall network throughput Due to large amounts of spectrum bands available. However, mm-waves have higher isotropic propagation and penetration path loss due to higher carrier frequencies. These technical obstacles in mm-wave technology [5] can be combated by using a spatial multiplexing technique for concurrent transmissions with a high directional antennas.

D2D communication [6] was investigated as a promising technology in the way of transfer user data on-demand between users equipment (UEs) to communicate with one another directly over cellular network bypassing the network core. Therefore, D2D exploit the heterogeneity of 5G network without increasing the processing and traffic loads on both access points (APs) and base stations (BSs). In addition to D2D, 5G mm-Wave HetNet can also provide with BH [7] and access links (AL) in communication between network elements.

Different multiplexing techniques are beneficial for mm-wave 5G networks, offering the ability to schedule concurrent transmissions. In Spatial Time-Division Multiple Access (STDMA) technique [8], a time slot can be allocated to multiple links with spatial scheduling. But based on interference levels, the number of flows for each slot will be limited rather than Time Division Multiple Access (TDMA) [9]. Which in TDMA each time slot is allocated to one link with only one flow. Furthermore, in Space-Division Multiple Access technique (SDMA) [9], a time slot can be allocated to multiple none interfering wireless links using a smart scheduling algorithm which offering a high spectrum utilization and enhancement user throughput.

Many literatures have pointed out the problem of optimal power allocation and concurrent transmission scheduling with interference reduction to maximize user throughput in 5G mm-wave HetNets [10]-[11]. Firstly, a formulation of power control and radio channel scheduling in mm-wave technology is presented in [12] without spatial multiplexing. In [13] with a little enhancement in average user throughput, time scheduling with interference reduction in HetNets based on the concept of Almost Blank Subframe (ABS). Where, AP allow to transmit with minimum interference level and mute all BS downlink transmissions proposed in enhanced Inter-Cell Interference Coordination (eICIC).

In mm-wave networks with high directional antenna, concurrently transmission scheduled with STDMA scheme is proposed in the literature [8] to improve average user throughput based on Quality of Service (QoS) metric. Framework in [14] and [15] consists of a joint radio scheduling and power allocation strategy in mm-wave HetNets using SDMA and water-filling algorithm. Considering QoS, SDMA scheme introduces a spatial multiplexing gain that enhances edge and average user throughput with less complexity. However in [16]-[17], the coexistence of D2D links shared the available spectrum bands for AL and BH links is proposed to improve the cellular network capacity. In [18], optimal power allocation and transmission scheduling problem for AL, BH and D2D links in small cells mm-Wave network band is studied with a centralized MAC scheduling scheme. But in this case this study missing to consider incorporating the QoS and NLOS transmission.

This paper proposes a jointly optimal power, and concurrent flows scheduling algorithm for allocating the available radio resources in mm-wave 5G HetNets. Which it is regarded as a highly systematically and computational optimization problem. In addition, for both LOS and NLOS transmission, we utilize D2D connections that share the spectrum with AL and BH links to significantly enhance total network throughput and radio spectrum utilization. In this scheme, spatial (space/time) multiplexing for concurrent transmission scheduling and an efficient power optimization algorithm based on the Genetic Algorithm (GA) [19] have been developed, aiming to maximize users' throughputs with minimum interference levels and maximize spectral utilization while ensuring the required QoS. Where, the proposed algorithm attempts to allocate time slots optimally for all AL, BH, and D2D links in each flow and selects the optimal number of concurrent flows for each link. Then it optimally selects transmit powers for all links in all concurrently transmitted flows. Comprehensive simulations show that the proposed GA scheme outperforms TDMA, STDMA, eICIC, and SDMA scheduling with a water-filling algorithm in terms of user throughput and radio resource utilization.

The remainder of the paper is organized as the following. Section II presents the system model and Section III formulates throughput analysis. Maximizing throughput problem formulation is proposed in Section IV. Then, concurrent radio resources transmission scheduling presented in Section V, followed by genetic based power allocation algorithm in Section VI. Simulations results are evaluated in Section VII followed by a summary in Section VIII.

II. SYSTEM MODEL

We consider a 5G mm-wave HetNet with AL, BH, and D2D links serving a large number of UEs for both uplink (UL) and downlink (DL) transmission [20]. D2D links shared the available spectrum of 5G HetNet in mm-wave bands with AL and BH links. Figure 1 illustrates a network model with one macro cell BS and various mm-wave APs deployed for capacity expansion. All network components are equipped with high-directional antennas and beamforming and share the same air interface. The cellular AL and BH connections for this model are considered as the available LOS and NLOS transmission links between (BS and AP),(BS and UE) and (AP and UE) and for D2D connections between UEs with each other's in the same BS or AP as indicated in [21]. In each superframe, BS processes concurrent transmission scheduling, transmission power level, and adaptive transmission duration for all links in this model.

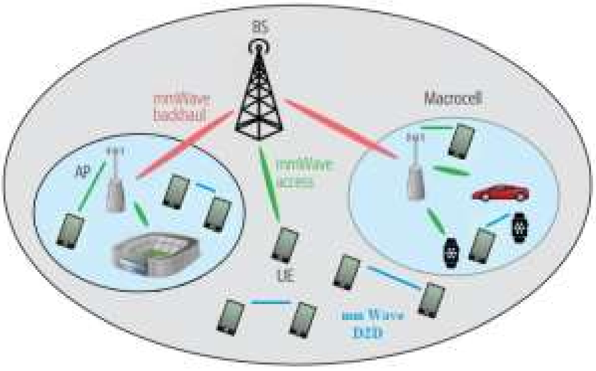

Fig. 1. Illustration of mm-Wave 5G HetNet with access and D2D links.

The channel access time in mm wave bands is divided into many sequential superframes. Each superframe illustrated in the IEEE 802.11ad and 802.15.3c draft standards [22] includes three major time intervals. Firstly, the beacon interval for BS control signaling messages and broadcasting. Then, the contention-based access period (CBAP) for all transmission requests transmitted to BS. Finally, the channel time allocation period (CTAP) for data transfers between all network elements is divided into several sequential N time slots.

Assuming directional transmission in mm-wave bands for all links in each superframe, with unchanged network topology and channel conditions that can be changed in the next superframe. Each link can be scheduled only once in each flow and can be allocated more than one time slot. Each time slot in CTAP can be allocated to multiple flows for different links with interference management to exploit more spatial multiplexing gain. Using interference management issues, the optimized concurrent transmission scheduling for AL and BH links can share the same bands with another concurrent transmission scheduling for D2D links to achieve outstanding throughput enhancement.

III. THROUGHPUT ANALYSIS

As shown in Figure 2, we assume that S concurrent transmission flows for AL and BH links and M concurrent transmission flows for D2D links sharing the same spectrum are scheduled in a given superframe with N time slots. Then the total network throughput allocated for all links is calculated mathematically, considering interference from reusing the available spectrum and ensuring the required QoS for all links.

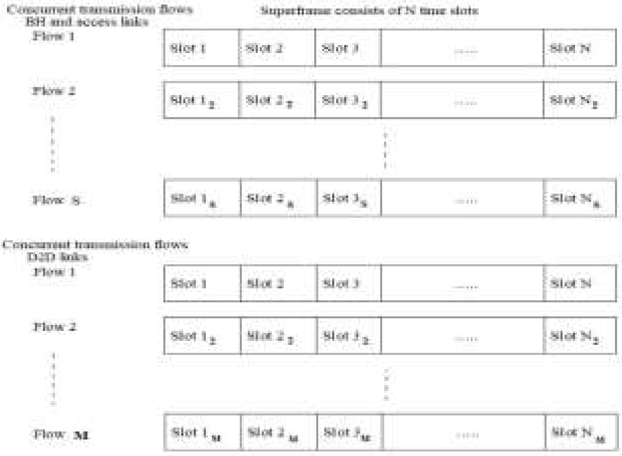

Fig. 2. Scheduling concurrent flows structure for BH, AL and D2D links.

For AL and BH links, in each concurrent flow the total time slots are allocated to all links in each superframe. Where, $n_{h,s}$ denotes the number of slots assigned to link h from H links and the flow s from S flow. According to the Shannon channel capacity equation, the achievable data rate of link h scheduled in flow s and interfered with another j th AL or BH link and dth D2D link sharing the same time slots in another flow can be calculated as

$$R_h^s = B\log_2\left[1+\frac{\partial_h P_h G_h L_h^{-1}}{\eta+\sum_j \partial_j P_j G_j L_j^{-1}+\sum_d \partial_d P_d G_d L_d^{-1}}\right] \tag{1}$$

Where p_h, p_j and p_d are the transmit power allocated to AL or BH link h and j and D2D link d whose share the slots with different flows. Then, the G_h, G_j and G_d are defined as the channel power gain for h and j cellular AL or BH links and for D2D pair link d, respectively as modeled in [23]. B defined as system bandwidth and the activity of h, j and d links can be determined by the resource sharing indicators ∂_h, ∂_j and ∂_d equal 1 if the link is active and share the same band. η is considered as the Additive White Gaussian Noise (AWGN) power spectral density with perfect channel state information. Finally, isotropic pathloss for cellular AL or BH link i and j and D2D link d are indicated as L_h^{-1}, $L_j^{-1}$and L_d^{-1}.we compute the isotropic pathloss for any link with LOS or NLOS transmission given by [23] as $l = (\frac{4\pi f}{c})^2 . d^n .SF$ where d is the distance in meters from transmitted node to the received one. C, f, SF and n is indicate the speed of light, carrier frequency in Hz, shadowing factor and the pathloss exponents, respectively.

For D2D communication with Z links and M concurrent flows, the total superframe time slots N are assigned to all links in each concurrent flow. Then, the number of slots allocated to link z in the flow m is denoted as $n_{z,m}$. According to the Shannon channel capacity equation, the achievable data rate of link z in flow m and interfered with another AL or BH link ℓ and a D2D link d sharing the same time slots with different flows can be calculated as

$$R_z^m = B \log_2 \left[1 + \frac{\partial_z P_z G_z L_z^{-1}}{\eta + \sum_l \partial_l P_l G_l L_l^{-1} + \sum_d \partial_d P_d G_d L_d^{-1}}\right] \tag{2}$$

Wherep_l, p_z and p_d are the transmit power allocated to AL or BH link ℓ and D2D pair link z and d whose share the same slots in different concurrent flows. Then, the channel power gain for ℓ, z and d links are indicated as G_l, G_z and G_d, respectively. The activity of ℓ, z link can be determined as ∂_l and ∂_z. Finally, $L_z^{-1} L_l^{-1}$are the computed pathloss for links z and ℓ.

IV. MAXIMIZING THROUGHPUT PROBLEM FORMULATION

The mathematical representation of maximizing total network throughput can be described as follows:

$$\max_{p} \left(\sum_{s=1}^{S} \sum_{h=1}^{H} R_h^s + \sum_{m=1}^{M} \sum_{z=1}^{Z} R_z^m\right) \tag{3}$$

$$\max_{n} \left(\sum_{h=1}^{H} \frac{R_h^s . n_{h,s}}{N} + \sum_{z=1}^{Z} \frac{R_z^m . n_{z,m}}{N}\right) \tag{4}$$

$$\max_{S,M} \left(\sum_{s=1}^{S} \sum_{h=1}^{H} \frac{R_h^s . n_{h,s}}{N.S} . s_h + \sum_{m=1}^{M} \sum_{z=1}^{Z} \frac{R_z^Z . n_{z,m}}{N.M} . m_z\right) \tag{5}$$

s. t.

$$P_s \leq P_{Max\ AL,BH} \tag{6}$$

$$P_z \leq P_{Max\ D2D} \tag{7}$$

$$R_h^s \geq R_{QoS\ AL,BH} \tag{8}$$

$$R_z^m \geq R_{QoS\ D2D} \tag{9}$$

$$\sum_j \partial_j P_j G_j L_j^{-1} + \sum_d \partial_d P_d G_d L_d^{-1} \leq I_{TH_{AL,BH}} \tag{10}$$

$$\sum_l \partial_l P_l G_l L_l^{-1} + \sum_d \partial_d P_d G_d L_d^{-1} \leq I_{TH_{D2D}} \tag{11}$$

The maximization problem indicated in (3)–(5) with constraints (6)–(11) is a mixed integer optimization problem in which the joint sharing of radio resources and optimal power allocation are used to maximize the total network throughput while dealing with interference issues for all BH, AL, and D2D links. In Equations (3)–(5), we aimed to optimally select the best values for the maximum power levels, the maximum number of time slots allocated for all links in each flow, and finally, the maximum number of concurrent flows allocated for all BH, AL, and D2D pair links in each superframe under three main different constraints. Firstly, in (6) and (7), the allocated power levels to all AL, BH and D2D links must be limited to the maximum allowable power $P_{Max\ AL,BH}$for AL and BH links and $P_{Max\ D2D}$ for D2D links. Then, in (8) and (9), the achievable rate for all AL, BH and D2D links must exceed the minimum acceptable QoS requirements $R_{QoS\ AL,BH}$ for AL and BH links and $R_{QoS\ D2D}$ for D2D links. Finally, in (10) and (11), the introduced interference for AL, BH, and D2D pair links must not exceed the predefined interference threshold level $I_{TH_{AL,BH}}$ for AL and BH links and $I_{TH_{D2D}}$ for D2D links.

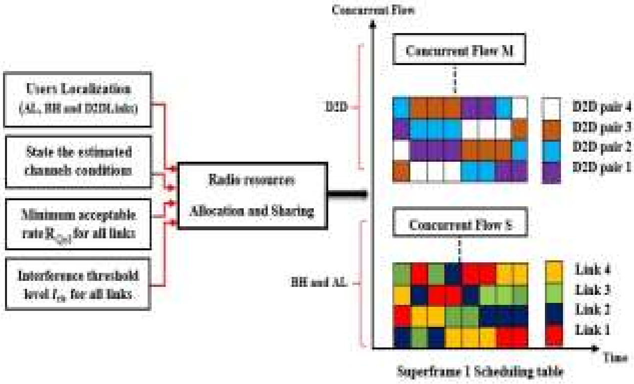

Fig. 3. Concurrent scheduling tables for BH, access and D2D links.

To fully exploit the spatial multiplexing gain, resource scheduling must have as many concurrent transmission flows as possible, but the number of flows must be coupled among the constraints with limited time and power and high interference levels. In the next section, we propose an intelligent concurrent flow schedule based on spatial (space/time) multiplexing for AL, BH, and D2D links in each superframe to fully exploit spatial multiplexing gain and maximize user throughput achieved for each link in this model.

V. CONCURRENT RADIO RESOURCES TRANSMISSION SCHEDULING

Based on the user's activities and locations, estimated channel conditions, and constraint parameters, the concurrent radio resources transmission scheduling algorithm starts to determine the number of active links and their required rates. Then, it states if only one AL or BH link allocates the channel or if more than one AL or BH link shares the same channel. Also, it states that if only one D2D pair allocates the channel or shares the channel with an AL or BH link, or more than one D2D link shares the same channel with more than AL or BH links. Finally, as shown in Figure 3, using GA with a heuristic search to find the optimal shared channel selection, optimal allocated time slots in each flow, and optimal number of concurrent flows scheduled for all AL, BH, and D2D links while ensuring QoS for all network links with a minimum interference level. This example shows the available radio resource scheduling table for one superframe. Using the concept of spatial multiplexing, four AL or BH links and four D2D links share the same spectrum and are allocated different time slots with different concurrent flows.

VI. GENETIC BASED POWER ALLOCATION ALGORITHM

Genetic algorithm based on Darwin's theory of evolution [19] is adaptive heuristic search optimization technique seeking to find the optimum solutions for a given objective function illustrate in (3) as an optimization problem under different constraints to maximize the total throughput with minimum interference level and ensuring the required QoS for all AL, BH and D2D links.

Algorithm 1: Optimal Power Allocation Algorithm.

```
Input
    • Concurrent flows Scheduling tables for AL, BH  links and for D2D pair links
    • Estimated channels characteristics and conditions
    • minimum acceptable rates $R_{QoS\ AL,BH}$, $R_{QoS\ D2D}$ for all links
    • minimum acceptable interference levels $I_{TH_{AL,BH}}$, $I_{TH_{D2D}}$ for all links
Initialization:
    • initial population Random Generate the group of sets to $P_{s,m} = \{P_h\} + \{P_z\}$ to each flow and for AL, BH and D2D according to the constraints that are given in (6 )-(11).
    • Generations = 0.
Iteration
    • Evaluate each power set according to the objective function of Problem (3).
    • Selection, mutation and Crossover on parents.
    • Generations = Generations + 1.
Stop if:
    • Maximum number of Generations is reached
    • OAverage change in fitness value ≤ Function Tolerance
Output
    • Optimum power levels for all AL, BH, and D2D links
```

Based on concurrent transmission scheduling for D2D AL and BH links, there will be a large number of links with many different concurrent flows to be transmitted simultaneously in each superframe. As a consequence, we apply the genetic algorithm to allocate optimally power level for all scheduled links in all flows seeking to maximize the average user throughput for all network links illustrated in Eq. 3 under different constraints indicated in (6)-(11) with minimum interference level and achieve the required QoS for all links as illustrated in power allocation Algorithm 1.

The GA starts randomly to initial population of individuals which called chromosomes. Each individual represents a randomly solutions called gens and have the same number of allocated power levels which we need to optimize and limited to predefined constraints in searching spaces of the optimization problems in Eq. (6)-(11) for all links. Then based on fitness function, the initial throughput are evaluated for each chromosome and then selecting the chromosomes with best fitness value to continue in the next generation. Then the chromosomes subject to crossover and mutation where gens sites are exchanged and insert random new genes. Then offspring executed by combining the best chromosomes with each other's so the new generations has high diversity and resistant to being exhausted. These steps are repeated and for each new generation, the current chromosomes become close to the optimal than the previous one. Until the chromosomes in the new generations don't having any significant enhancement than the previous ones so the optimum value of the fitness function is found or the predefined maximum number of generations is reached. The population is ended and the algorithm generates a set of optimal power values for all links and to all flows in this system that achieve a high improvement in total network throughput.

VII. SIMULATION RESULTS AND DISCUSSION

Using a single Manhattan Grid model in [14]-[15], we consider a 5G HetNet mm-wave network model is equipped with 100 UEs for AL, BH and D2D pair uniformly dropped in the streets with 200 meters long and 30 meters width and serviced by a single BS and four APs. The network simulation parameters are explained in Table Ⅰ.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Carrier frequency	28 GHz
System bandwidth	1 GHz
Pathloss exponent	LOS: 2.1 NLOS: 3.17
Number Cellular UEs	100-300
Number D2D pairs	20
Maximum D2D pair distance	100 m
Shadowing	Lognormal with zero mean 5.8 dB standard deviation
Inter-link interference threshold	1 × 10−8 W
Antenna array	(Vertical x Horizontal) 8x16 for AP 4x4 for UE (access and D2D)
Maximum transmission power level	30 dBm for AP/BS 20 dBm for UE (access and D2D)

In comparison with different joint power and radio resources allocation algorithms with different multiplexing techniques based on STDMA, SDMA with water filling algorithm, TDMA and eICIC schemes our proposed approach based on GA introduces appreciable improvement in both average and edge user throughput as illustrated in Figure 4. The cell edge users throughputs are explained as 5th percentile point of the cumulative distribution function (CDF) of average users throughputs. Due to exploiting D2D pair connections with both AL and BH links and using optimal power allocation and intelligent concurrent flow scheduling, many different links can transmit concurrently with interference reduction or cancellation.

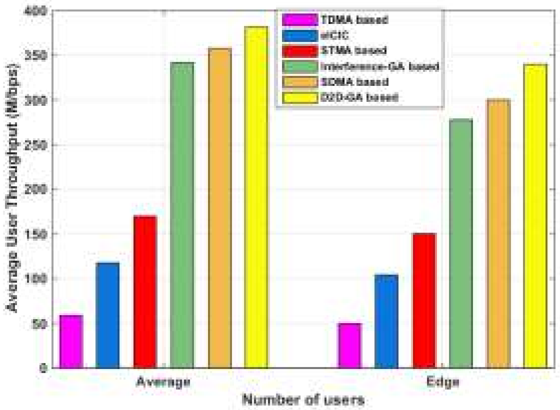

Fig. 4. Edge and average user throughputs with different algorithms

Figure 4 shows that the gain of our D2D-GA based scheme where D2D pair links can share the spectrum allocated to AL and BH links based on concurrent flows scheduling grows by 648%, 325%, 222% and 107% against the algorithms based on TDMA, eICIC, STDMA and SDMA respectively in both average and edge user throughputs for 100 AL or BH and 20 D2D pair links. For an interference-GA based strategy, the concurrent flow scheduling is accrued for only the AL and BH links. On the other hand, D2D pair links are allowed to share the available spectrums with higher inference levels. Our scheme grows by 580%, 290% and 210% against benchmark TDMA, eICIC and STDMA.

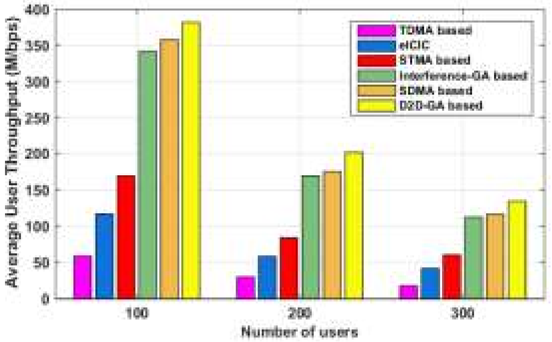

Fig. 5. Average user throughputs evaluating with different numbers of users

Figure 5 shows the average user throughput with different numbers of users such as 100, 200, and 300 users respectively. Due to limited system bandwidth the average throughput for all links will be reduced by increasing the number of users. However, with the availability of D2D links, spatial multiplexing gain and optimal power level allocated for each link, our algorithm still achieves significant enhancement in average user throughput in the case of heavy users' density. In this case, the achievable average throughput gain of our D2D-GA based technique grows by 650%, 325%, 224% and 116% against TDMA, eICIC, STDMA and SDMA respectively. For the interference-GA based strategy, our scheme grows to 628%, 295% and 210% rather than TDMA, eICIC and STDMA schemes.

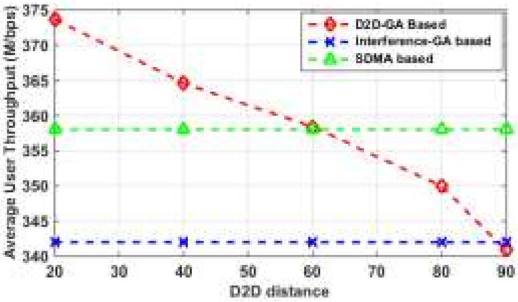

Fig. 6. Average user throughputs evaluating for different D2D links distance with 100 users

Figure 6 shows the average throughput of 20 D2D pairs and 100 AL or BH links with the distance of a D2D pair link. The average throughput for all D2D links decreases as the distance d increases. At d = 20 meters, the average user throughput is 342 Mbps for the interference-GA technique, 358 Mbps for SDMA and finally 374 Mbps for the D2D-GA technique. When d exceeds 60 m, the average user throughput of the D2D-GA technique is less than that of the SDMA technique, and when d exceeds 88 m, it is less than that of the interference-GA based algorithm. So the distance between D2D pairs must be limited and not be large. Therefore, the availability of D2D links sharing the spectrum with AL and BH links and using optimal power and intelligent concurrent flow scheduling based on GA gives better performance in spectrum utilization and achieves a significant enhancement in average throughput for all users in the network than the other algorithms based on TDMA, eICIC, STDMA and SDMA respectively.

VIII. CONCLUSION

In this paper, the availability of D2D links in heterogeneous 5G mm-wave network with AL and BH connections was addressed. The problem of maximizing the average and edge user throughput was illustrated and decomposed into concurrent scheduling flows for AL, BH and D2D links and optimal power allocation for all links in this network. Using D2D connection, heuristic GA for optimal power allocation and updated space and time scheduling table for simultaneous concurrent transmission is applied to maximize the user throughput with minimum interference levels and ensuring the required QoS for all links.

REFERENCES

[1] N. Radio, Y. Zhang, M. Tatipamula and V. K. Madisetti, "Next-Generation Applications on Cellular Networks: Trends, Challenges, and Solutions," in Proceedings of the IEEE, vol. 100, no. 4, pp. 841-854, April 2012.

[2] M. Agiwal, A. Roy and N. Saxena, "Next Generation 5G Wireless Networks: A Comprehensive Survey," in IEEE Communications Surveys & Tutorials, vol. 18, no. 3, pp. 1617-1655, third quarter 2016.

[3] E. Gures, I. Shayea, A. Alhammadi, M. Ergen and H. Mohamad, "A Comprehensive Survey on Mobility Management in 5G Heterogeneous Networks: Architectures, Challenges and Solutions," in IEEE Access, vol. 8, pp. 195883-195913, 2020

[4] X. Wang, L. Kong, F. Kong, F. Qiu, M. Xia, S. Arnon, G. Chen, Guihai, "Millimeter Wave Communication: A Comprehensive Survey," in IEEE Communications Surveys & Tutorials, vol. 20, no. 3, pp. 1616-1653, third quarter 2018.

[5] S. Geng, J. Kivinen, X. Zhao and P. Vainikainen, "Millimeter-Wave Propagation Channel Characterization for Short-Range Wireless Communications," in IEEE Transactions on Vehicular Technology, vol. 58, no. 1, pp. 3-13, Jan. 2009.

[6] M. S. M. Gismalla, A. I. Azmi, M. R. B. Salim, M. F. L. Abdullah, F. Iqbal, W. A. Mabrouk, M. B. Othman, A. Y. I. Ashyap, A. S. M. Supa'at, "Survey on Device to Device (D2D) Communication for 5GB/6G Networks: Concept, Applications, Challenges, and Future Directions," in IEEE Access, vol. 10, pp. 30792-30821, 2022.

[7] M. Jaber, M. A. Imran, R. Tafazolli and A. Tukmanov, "5G Backhaul Challenges and Emerging Research Directions: A Survey," in IEEE Access, vol. 4, pp. 1743-1766, 2016.

[8] J. Qiao, L. X. Cai, X. Shen and J. W. Mark, "STDMA-based scheduling algorithm for concurrent transmissions in directional millimeter wave networks," 2012 IEEE International Conference on Communications (ICC), pp. 5221–5225,2012.

[9] E. A. Jorswieck, P. Svedman and B. Ottersten, "Performance of TDMA and SDMA based Opportunistic Beamforming," in IEEE Transactions on Wireless Communications, vol. 7, no. 11, pp. 4058-4063, November 2008.

[10] A. Mamane, M. E. Ghazi, G. Barb and M. Oteșteanu, "5G Heterogeneous Networks: An Overview on Radio Resource Management Scheduling Schemes," 2019 7th Mediterranean Congress of Telecommunications (CMT), pp. 1-5, 2019.

[11] Y. Xu, G. Gui, H. Gacanin and F. Adachi, "A Survey on Resource Allocation for 5G Heterogeneous Networks: Current Research, Future Trends, and Challenges," in IEEE Communications Surveys & Tutorials, vol. 23, no. 2, pp. 668-695, Secondquarter 2021.

[12] H. Shokri-Ghadikolaei, L. Gkatzikis, and C. Fischione, "BeamSearching and Transmission Scheduling in Millimeter Wave Communications," in 2015 IEEE International Conference on Communications (ICC), pp. 1292–1297, June 2015.

[13] D. Lopez-Perez, I. Guvenc, G. de la Roche, M. Kountouris, T. Q. S. Quek, and J. Zhang, “Enhanced Intercell Interference Coordination Challenges in Heterogeneous Networks,” IEEE Wireless Communications, vol. 18, no. 3, pp. 22–30, June 2011.

[14] Y. Li, E. Pateromichelakis, N. Vucic, J. Luo, W. Xu and G. Caire, "Radio Resource Management Considerations for 5G Millimeter Wave Backhaul and Access Networks," in IEEE Communications Magazine, vol. 55, no. 6, pp. 86-92, June 2017.

[15] Y. Li, J. Luo, W. Xu, N. Vucic, E. Pateromichelakis and G. Caire, "A Joint Scheduling and Resource Allocation Scheme for Millimeter Wave Heterogeneous Networks," 2017 IEEE Wireless Communications and Networking Conference (WCNC), pp. 1-6, 2017.

[16] M. Noura and R. Nordin, “A survey on interference management for Device-to-Device (D2D) communication and its challenges in 5G networks,” Journal of Network and Computer Applications, vol. 71, pp. 130–150, 2016.

[17] A. A. Rosas, M. Shokair, M. I. Dessouky “Genetic Based Approach for Optimal Power and Channel Allocation to Enhance D2D Underlaied Cellular Network Capacity in 5G” Computers, Materials & Continua (CMC), Vol.72, No.2, pp.3751-3762, March 2022.

[18] Y. Niu, C. Gao, Y. Li, L. Su, D. Jin, and A. V. Vasilakos, “Exploiting Device-to-Device Communications in Joint Scheduling of Access and Backhaul for mmWave Small Cells,” IEEE Journal on Selected Areas in Communications, vol. 33, no. 10, pp. 2052–2069, Oct 2015.

[19] K. Y. Lee; M. A. El-Sharkawi “Modern Heuristic Optimization Techniques: Theory and Applications to Power Systems” Wiley-IEEE Press, 2008.

[20] M. R. Akdeniz, Y. Liu, M. K. Samimi, S. Sun, S. Rangan, T. S. Rappaport, and E. Erkip, “Millimeter Wave Channel Modeling and Cellular Capacity Evaluation,” Selected Areas in Communications, IEEE Journal on, vol. 32, no. 6, pp. 1164–1179, 2014.

[21] Y. Li, J. Luo, M. H. C. Garcia, R. Boehnke, R. A. Stirling-Gallacher, W. Xu, and G. Caire, “On the beamformed broadcasting for millimeter wave cell discovery: Performance analysis and design insight,” IEEE Transactions on Wireless Communications, vol. 17, no. 11, pp. 7620–7634, Nov. 2018.

[22] “IEEE Standard for Information Technology–Telecommunications and Information Exchange between Systems–Local and Metropolitan Area Networks–Specific Requirements-Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 3: Enhancements for Very High Throughput in the 60 GHz Band,” IEEE Std 802.11ad-2012 (Amendment to IEEE Std 802.11-2012, as amended by IEEE Std 802.11ae-2012 and IEEE Std 802.11aa-2012), pp. 1–628, Dec 2012.

[23] T. S. Rappaport, G. R. MacCartney, M. K. Samimi, and S. Sun, “Wideband millimeter-wave propagation measurements and channel models for future wireless communication system design,” IEEE Trans. Commun., vol. 63, no. 9, pp. 3029–3056, Sept. 2015.