Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Resource Allocation by PSO-based Interference Optimization in D2D Communication for 5-G Network

Abhishek Kumar Yadav[1], Dr. Ritesh Baranwal[2], Ravi Prakash[3]

[1]M.tech Scholar, Department of Electronics Engineering, VBSPU Jaunpur.
[2]Asst. Profeesor, Department of Electronics Engineering, VBSPU Jaunpur.
[3]Professor, Department of Electronics Engineering, VBSPU Jaunpur.
Email: Ay2000803@gmail.com

Connectivity with Device-to-Device (D2D) is one of the groundbreaking developments to achieve the 5Gnetworks goals. D2D communication improves network efficiency through the reuse of cellular user (CU) capabilities, especially in indoor / local communication. The D2D pair interferes with one another by reusing the CU resource, resulting in the resulting throughput degradation. We therefore provide a PSO-focused resource allocation approach for D2D communication for 5 G networks in the research. PSO is one such optimization algorithm. PSO's goal is to look for the optimal solution in search space. In addition, a mode selection strategy based on PSO mapping is proposed. Results of the simulation show that use of the new scheme would effectively ensure cellular coverage and network performance. MATLAB carried out a performance review to test our scheme.

Keywords: Resource Allocation, D2D communication, Particle Swarm Optimization, Interference.

1. Introduction

Experts are expecting an unprecedented increase in anticipated growth in mobile broadband network traffic in the upcoming years, several social media platforms, gaming, and streaming video have become popular. Despite significant advancements in fourth generation (4G) wireless technologies, it is anticipated that cellular networks would not be able to support the necessary bandwidth unless there is a significant shift towards smaller cells. The first wave of 4 G services was gradually launched across Europe, providing a standardized network for mobile broadband networks anytime, anywhere, and everywhere.

The number of people using smartphones has increased, and with it, so has the need for mobile data. In response to these demands, 5 G emerged as a more dependable option with a 10,000 Mbps download speed[1]. We require new connecting device technologies with the introduction of 5 G to prevent a period of poor performance at the cell edges, call drops, and reputational damage. Therefore, when the devices connect locally with the base station, more than 90% of the contact should be local.

Enhancing device performance requires the usage of D2D (Device-to-Device) communication, which recycles mobile users' bandwidth resources[2]. Instead of utilizing the base station for communication, mobile devices can link directly to one another with this technology by sharing the bandwidth resource from other mobile devices. Spatial reuse of radio resources can increase spectral efficiency, and a reduction in transmission power will extend the lifespan of the devices. Reusing frequency resources may improve the overall mobile communication network's spectral efficiency, however interference is a major issue that can make it challenging to provide cellular consumers with QoS (Quality of Service). This is due to D2D communication interfering with mobile users' experience and its frequency resource is reused by D2D applications.

Long-term advancement of evolution-release 12 (LTE) technology produced the D2D communication system (D2D)[3]. A D2D is a peer-to-peer link that enables direct communication between nearby LTE-based devices. To enhance the productivity, spectrum quality, energy consumption, and latency, a D2D communication was employed. This is thought to reduce base station traffic offload and transmission latency, while also improving network spectral quality and energy consumption[4].

D2D networks' reuse of resources attributed to cellular users[5] is an important part of this. Offering wireless networks is suffering from a lack of resources so optimum resource allocation is required. The networks are initially allocated in a wireless network to cellular users, and then assigned to D2D pairs as per requests. In the implementation of this technology the Particle Swarm algorithm was proposed. [6]. [18].

Connectivity of D2D in mobile network was thought to be a viable technology for the spectrum performance[7]. Also, D2D will reduce network charging, increase cell coverage and decrease battery consumption for devices. D2D is a hot subject of research because of those advantages[8]. The use of cellular network-based D2D connectivity can be considered an effective method of making use of the infrastructure.

Regarding D2D contact over the cellular network, one of the main issues is space distribution. There are currently two methods that D2D and cellular users can share information: orthogonal and non-orthogonal.

On this, an algorithm based on the interference-conscious graph principle was provided[9]. The authors of [9] concentrated on the interference that arises when a transmitter and a receiver use almost the same channel that is already set aside for other reception communications. In order to assist the interference evaluation and produce a resource allocation solution that is almost optimal, each consumer is viewed as a vertex in an interference network, with each vertex possessing specific characteristics (link, resource, and cluster).

Users are allocated the resource using the interference value or Signal-to Interference and Noise Ratio (SINR).

Since multi-criterion problems allow multiple competing areas to be optimized simultaneously, by merging them into a single problem with criteria We are able to resolve these issues[10]. Communication with D2D will interfere with the principal cellular network. To prevent this issue, the network should arbitrarily distribute its resources and choose a user-friendly mode. The authors of [11] present a simultaneous mode selection and resource allocation problem that maximizes unit throughput while providing the lowest possible level of rate guarantee. It is suggested to use a fitness function to express the limitations of a penalty function and map solutions to particles as part of a selection mode and resource allocation scheme.

Many previous research addressed the issue of multiple D2D pairs with one CU sharing same resource size. A suboptimal greedy algorithm has been proposed in[12] that can achieve maximum the spatial reuse of radio resources by allowing D2D links to be transmitted simultaneously on the same network. The cellular user can get more interference when greater than one D2D pair shares the same bandwidth resource in one CUE. To address this problem, we expand the PSO-based method in [13] to multiple D2D pairs in this study. In this scenario, the PSO ought to employ an interference avoidance strategy that permits one CU and one or more D2D pairs to share a frequency resource. Furthermore, a mode selection strategy is employed to select whether D2D couples should share same resource frequency following the PSO's mapping phase.

We implement a resource allocation technique for D2D users for the 5 G networks based on the PSO algorithm to mitigate the resource allocation conflict. This strategy allocates resources to D2D users with high fitness values; we give high priority throughout the resource allocation phase.

The remainder of the research is then organized accordingly. Beginning with the software model in Section II, we will briefly present the traditional PSO and then explain in detail our proposed method in Section III. Quality analyzes and outcomes have been addressed in Section IV. Eventually, the paper concludes in Section V.

2. Literature Review

When the network permits D2D mode and when it permits CU mode are the main problems. While the interacting devices are subject to deep fading in the same proximity field, the network could not allow the D2D contact. In addition, there are many scientists, people from the industry; academics concentrate their attention on solving this problem and suggested several efficient methods for selecting the mode for next-generation networks. D2D contact underneath a cellular network was suggested in the authors, allowing local services with minimal cellular interference. Additionally a mode selection strategy was suggested for single cell and multi-cell system.

In[15], the authors suggested D2D communication in a resource allocation and selection mode that is power-efficient. The fundamental flaw in this plan is that the device needs to be placed beneath a macro cell, and the authors failed to account for the device's remaining battery life or multiple factor relationship distance. In [16], the authors proposed mode selection strategies to address this problem. A number of network characteristics, including noise level, connection gain, and signal to interference plus noise ratio, are considered while choosing a mode.

One of the significant parameters which [16] does not consider is the distance between the ties. In [17] the authors suggested a machine account mode selection strategy for both the distance from the D2D connection and the distance from the cell.

Through the reduction of intra-cell interference and improvement of spectral efficiency, network-enabled D2D communication for next-generation was reported by the researchers in [18]. This technology increases spectrum usage while lowering energy consumption. A plan for choosing a mode and assigning spectrum in band overlay for D2D communication was put forth by the researchers in [19]. In contrast to all other D2D transmissions, an active D2D user sets the first interference frequency over the allotted spectrum. A threshold will be used by carrier sensing to determine the transmission mode if the dvoted D2D users obtain the interference and other necessary data for all of the allotted spectrum. Selecting the spectrum that will minimize side load on the base station and increase network efficiency is one of the tools. The authors assessed the threshold value using the statistical technique in [20] and suggested a power control approach to guarantee that the CU consumer's violation of SINR as a result of cross-mode intervention is kept up below a specific threshold. In order to maximize transmitting efficiency in the case of an uplink, the authors in [21] evaluated the transmit power and ideal strength for CU and D2D users using a statistical approach.

In [22] authors suggest Particle swarm optimization (PSO) focused power allocation to reduce the conflict between users of the CU and D2D as well as to increase the entire system throughput. The only tool Up-Link is used.

In [23], resource allocations proposed by the authors are distributed based on resource block demand from those users in inactive mode. The only tool Up-Link is used.

In [24], the author proposes resource allocation algorithms for "One to Many Sharing" and "Many to Many Sharing" with a goal of optimizing device Capability. Both resource allocation systems are used up-link and down-link.

D2D Communication

The D2D communication is for sure to take up the place in coming 5G communication, the reason of its lies in the communication system which used to happens few years back, which describes that in the earlier communication system when two subscriber would have initiated a call, it was most probable that they exist in a far distant place, but in the current scenario the demand of data is more.

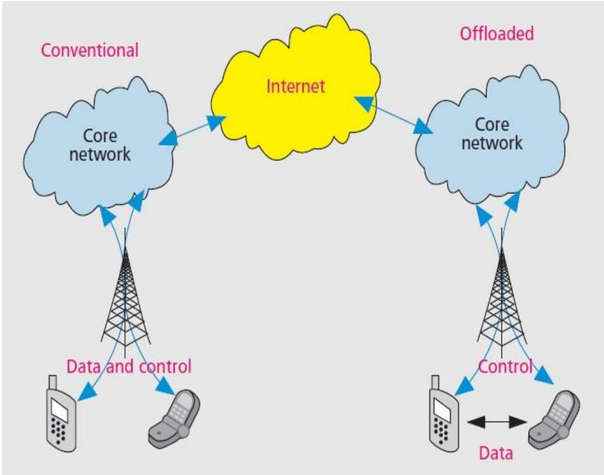

Figure1: D2D Communication

As per [25], which states that more than 80% communication will be laid on data and rest will use voice call. With this phenomenon taking shape it was observed that in spite of being at distant places the user will fall densely at a particular region. The problem and scenario presented above is exactly addressed by D2D communication [26]. D2D communication in cellular networks is defined as direct communication involving two mobile users without passing over a core network or a base station (BS).

Both in-band and out-of-band D2D communication fall under these two categories.

In-band D2D

Communication in this category takes place on a licensed network (i.e. all D2D and wireless networks using wireless spectrum).

Fast regulation of the licensed (i.e., cellular) spectrum is usually the explanation for the in-band contact range. Researchers believe it is not easy to manage the interference in the unlicensed spectrum which imposes restrictions on the quality of service (QoS) delivery. The in-band D2D is further broken down into the sublay and overlay categories. Link Cellular and D2D share the identical radio capabilities that underlie D2D communication. In addition, the D2D connections are equipped with dedicated cellular services in overlay communication.

Out-band D2D

Under this category D2D touch uses spectrum not approved. The purpose for using out-bands D2D communication is to reduce the interference problem amongst D2D and cellular connections. Utilizing unlicensed spectrum needs extra interface, so other wireless systems are usually introduced, such as Bluetooth, Wi-Fi Direct. The out-band D2D is furthermore broken down into autonomous managed communication.

The cellular network controls all out-band D2D communication, including controlled out-band D2D communication involving a second interface or technology. However, users are still in charge of D2D communication involving a second interface or technology that is not controlled by the network. Unlike D2D in-band, there is no possibility of interference with out-band D2D activity since it does not take place in the cellular spectrum. Nevertheless, Users are able to access D2D cellular data simultaneously, although D2D out-band is limited to mobile devices having two wireless networks (like, LTE and Wi-Fi).

3. SYSTEM MODEL AND PROBLEM FORMULATION

We are witnessing a downlink transmission scenario network that consists of direct D2D connection and traditional cellular communication. When there is no interference from BS, cellular contact occurs between two D2D users and the cellular user. A downlink scenario is depicted in Figure 2, where UE6 transmits in touch downlink mode while UE1, UE2, UE7, and UE8 broadcast in D2D mode. The rest of the UE3, UE4, and UE5 units are located inside the cell region.

We take M cellular users and N D2D couples, where Cm, m=1,2... M, and Dn denotes a D2D pair {DTn, DRn} while DTn and DRn, where n = 1, 2,... N represents the simultaneous D2D transceiver. Further, we assume that D2D and BS transmitters have PD and PB capacity, meaning that every cellular user is allocated to a single channel (i.e., channel number matching the cellular users).

The power of BS transmission allotted to each channel is expressed as PB/K, K is the channel number. To determine the interference, we must determine the type of channel that CU and one or more D2D sets supply. Channel gain is fading to a small scale and direction loss dependent on distance. We used the minor device for a fad. The formula for calculating path loss to app connections is as follows: Route losses for BS:

$$\mathrm{PL(d)} = 35.24 + 35 * \log(\mathrm{d}) \quad (1)$$

D2D connection path loss (which occurred between D_{Tn} and C_m or between D_{Tn} and D_{Rn})

$$\mathrm{PL(d)} = 40.3 + 40 * \log(\mathrm{d}) \quad (2)$$

The d is distance (kilometers).

The following can be used to evaluate interference for cell users:

$$I_{C_m} = \sum_{i \in N} P_D^K \, G_{DT_i,C_m}^K \quad (3)$$

Here, G_{DT_i,C_m}^K, describes the channel gain between the D2D transmitter of DT_i to cellular users C_m at the k^{th} channel.

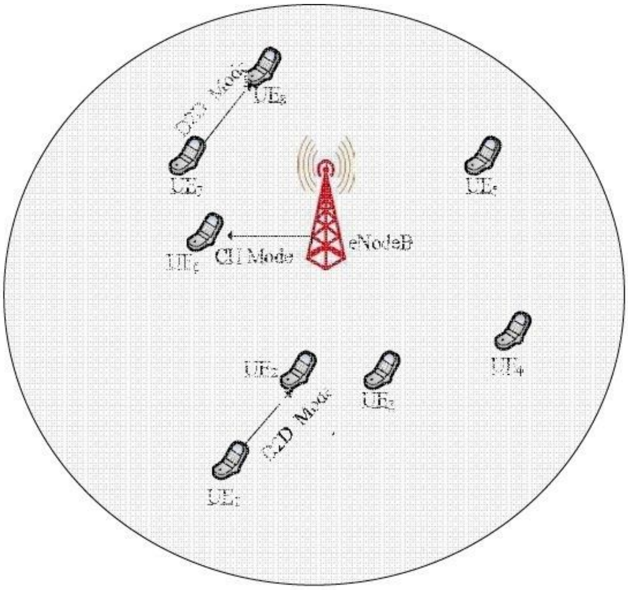

Figure 2: The 5 G Networks: An Analogue of Communication

The Interference at the end of the D2D users:

$$I_{D_n} = P_C^k G_{C_{m,D_{R_n}}}^k + \sum_{n=1,n\neq i}^{N} P_D G_{D_{T_{n,D_{R_i}}}}^k \quad (4)$$

Here $G_{C_{m,D_{R_n}}}^k$ describes channel gain amongst cellular users and D2D users at k^{th} channel and $G_{D_{T_{n,D_{R_i}}}}^k$ the confirmed D2D pair channel gain for receiver amongst other D2D transmitters on the k^{th} channel.

Now that we are looking at a 5 G network, we have to assign D2D pairs to channels that are designated for cellular users. In this network, cellular users have high priority and are given channel allocation precedence. To accommodate D2D user numbers, channel allocation to D2D pairs truly needs to be done in a way that minimizes total interference. To reduce interference values caused by D2D pairings, we must initially identify interference throughout all users and then apply optimization techniques. We also observed both instances. The case No 1: Single CU and Single D2D pair share a single resource block (up to 15^{th} D2D pair), when there are more D2D pairings than there are channels.

Therefore, the objective function for problem we have is as follows:

$$\text{minimize} \sum_{i=1}^{N} I_{D_i} \quad (5)$$

4. THE PROPOSED RESOURCE ALLOCATION METHOD

Particle Swarm Optimization (PSO)

PSO is a meta-heuristic technique which is introduced by Kennedy and Eberhart in 1995. It is used to simulate the nature of bird's gesture or schooling of fish and flock of insects to discover the optimal solution. Figure 2.4 details the Particle Swarm Optimization. The PSO algorithm, which contains a population called as a swarm and each participant (birds or fishes or insects) is viewed as a particle. The position and velocity of every particle are represented at any given time. Every particle adjusts its velocity, which is controlled by laws, in order to move in the direction of a better position.

Swarm particles are initialised at random in a multi-dimensional search space. The dimensionality of the search space is determined by the problem that has to be addressed. The particles take off and land at various points in the multi-dimensional search space at dynamic velocities. The position and velocity of each particle are represented at any given time. The location of the particle indicates a potential fix for the issue. The guidelines are based on the behavioural model of flocking birds. Every particle in PSO holds two values: the best position it can achieve on its own (local best) and the best position the particle community as a whole can achieve (global best).

In every iteration, the particle's position is updated based on following factors:

- Own way (take it on its own)
- The best prior position (based on experience)
- The particle with the best previous position among all of its neighbours.

Basic PSO algorithm steps are given below:

1. Give each particle an initial dimension of d.

2. Set each particle's initial position and velocity at random

3. Determine fitness value of the particle as,

3.1 Particle fitness value and particle best value should be compared. Update pbest to current value and location if particle value at that moment is better to pbest.

3.2 Particle fitness value should be compared to the global best gbest value. Update gbest to current value and location if particle value at that moment is better to gbest.

3.3 Update the particle's position and velocity based on equations 6 and 7.

Each iteration modifies the particle's velocity and position in the following ways:

$$\mathrm{vi}(\mathrm{t}+1) = \omega \mathrm{vi}(\mathrm{t}) + \mathrm{v1r1}\big(\mathrm{pi} - \mathrm{xi}(\mathrm{t})\big) + \mathrm{c2r2}\big(\mathrm{pg} - \mathrm{xi}(\mathrm{t})\big) \quad (6)$$

$$\mathrm{xi}(\mathrm{t}+1) = \mathrm{xi}(\mathrm{t}) + \mathrm{vi}(\mathrm{t}+1) \quad (7)$$

Continue from step 3 until the stop condition is reached.

Proposed Work Algorithm

PSO's ultimate goal is to identify the optimal schedule. The fitness function evaluates the particle's fitness at every iteration. Next, using the formula, the particle's fitness is contrasted to the P and G best values. If current value is better than previous solutions, the new value will be updated as g best value. Particle position is a bit vector where the number of resource allocation type is mentioned. Particle velocity is a bit vector where the velocity represents the adjustment of solutions in the resource allocation. Based on this vector value, allocation needs to be re-evaluated. Subtraction operator in PSO equation is utilized to determine the gap between the two relevant resource allocation solution's differences. Addition operator in PSO equation is utilized to identify the update about particle's velocity. The Particle velocity update happens due to current velocity, local best position and global best position. The Multiplication operator is utilized to update particle's position. To obtain the global optimal resource allocation solution, there is a need to formulate a resource aware local fitness.

PSO technique is primarily optimized for real value in a continual domain. In PSO method, Particle represents a bird and particle swarms identify the bird group. A particle is encoded and it represents a Resource schedule. The ultimate aim of PSO is to find the best resource schedule. At every iteration, particle's fitness is determine by the fitness function. Particle fitness is checked with P best and G best value based on the formula. If current value, i.e schedule is better than previous solutions, the new value is updated as g best value. Sometimes PSO terminates sometime when no improvement is found in solutions or maximum variety of trials is reached.

1. The PSO algorithm begins with the creation of starting particles, which assign initial velocities after listening to D2D and CU users' SINR.

2. PSO determines the optimal position and function value at particle point by computing the objective function.

3. It chooses new velocities according to the current velocity, the optimal positions of each individual particle, and the optimal locations of their neighbors.

4. Afterward, iteratively altering the particle placements (new position is previous one plus velocity, modified to hold particles within limits), speeds, and neighbors.

5. Iterations keep on until the procedure reaches the maximum iterations (MaxIt), which is the stopping criterion.

6. Therefore, we may use the formula below to compute the optimized throughput of D2D and CU users.

The Shannon Capacity is used to calculate the network throughput. The network throughput is ascertained as follows, if the channel's bandwidth is W and optimized interference computed by of PSO is Id:

$$\mathrm{Throughput} = \mathrm{B} * \log2\,(1 + \mathrm{S/N}) \qquad (8)$$

Equation 8 is used to calculate the throughput and spectral efficiency of the network.

5. ANALYSIS OF PERFORMANCE AND RESULT

This section outlines the numerical overall outcome for 5G D2D communication networks using a PSO-based resource allocation mechanism. MATLAB is used for results analysis. Each program runs 100 times, averaging the results before plotting the simulation graph. The systems are dispersed at random over the base station's coverage region. Half-duplex (HD) and full-duplex (FD) D2D communication, in which the user reuses uplink resource blocks from other CU users, are supported by the network.

Table-1: Computing Simulation Parameters of Interference

Parameters	Values
Cell Radius	500 mt
Carrier Frequency	2.10 GHz
Number of D2D User	6.0
Number of CU User	15.0
Number of Channel	15.0
Transmission of Power by BS	78.0 dBm
Transmission of Power by Device	24.0 dBm
Channel Bandwidth	1800 KHz
Noise Figure of Device	-116 dBm
Simulation Type	Monte.Carlo

Table-2: PSO Simulation Parameters

Parameters	Values
Decision Variable Numbers	10.0
Lower Bound.Variables	10.0
Upper Bound.Variables	10.0
Maximum iteration	10.0
Population.Size	100.0
Inertia.Weight	1.0
Damping.Ratio	0.99
Personnel Learning.Coefficient	1.5
Global Learning.Coefficient	2.0
Best Cost	INF

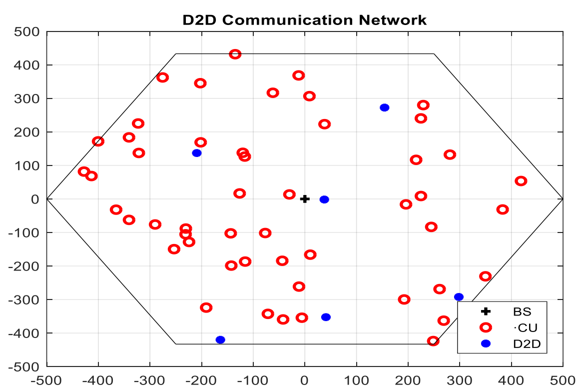

Figure 3: D2D Communication Network

A D2D network for communication is seen in Figure 3. When both the transmitter and receiver distances and the base station are sufficiently separated from the D2D pair, D2D communication can occur.

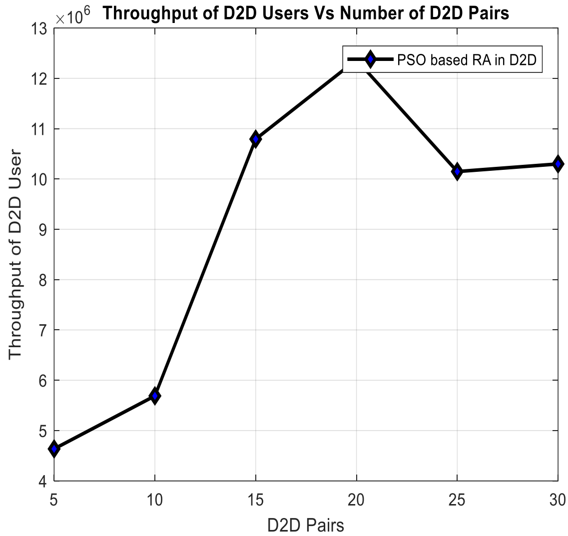

Figure 4: D2D Throughput Vs D2D pairs

Figure 4 depicts graph between D2D Users throughput and D2D pairs. We thought initially of a single one resource sharing scheme where every User whether it is D2D User or CU User uses the different resource block one at a time. So, our situation is single resource sharing up until the 20th D2D pair and thus the throughput shows increment.

Following the 20th D2D pair, we have taken into consideration a multi-resource sharing strategy in which D2D users and CU users share a single resource block and thus from 21th D2D pair the throughput decreases gradually till 25th D2D pair. After 25th D2D pair the throughput is improved showing that whether D2D User or CU User changes the position and start using different resource block.

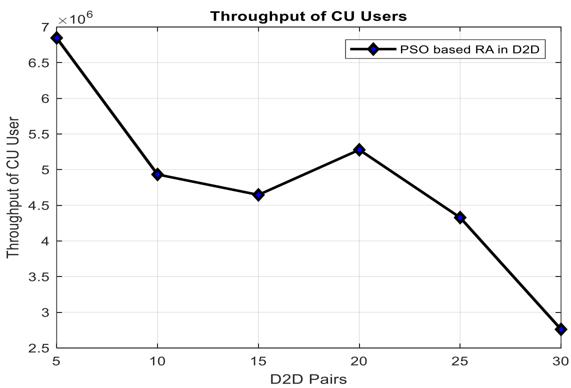

Figure 5: CU Throughput Vs D2D pairs Graph

Above Figure 5 depicts the throughput of D2D pairs for the CU Users vs. In this project we considered 15 users of the CU. Base Station (BS) initially allocates one channel to each CU user and sends requests to BS when D2D users need blocking. BS then allocate the same resource block to D2D Users also, this results in interference that's why the resultant throughput of CU Users decreases. So after 5th D2D pair Users of CU and D2D share an identical resource block thus overall throughput of CU Users degraded.

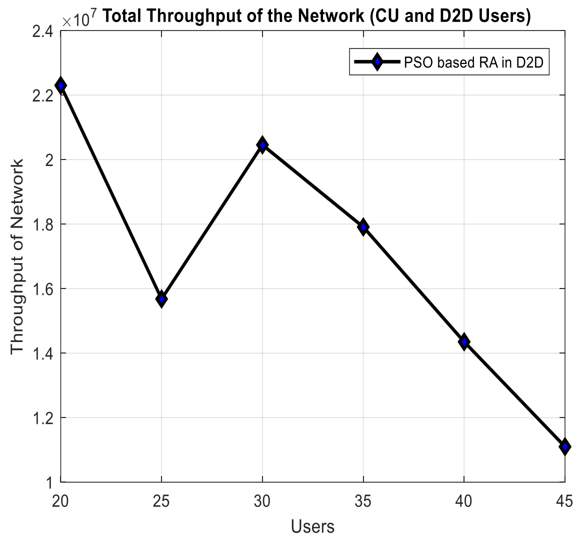

Figure 6: Total Network throughput (D2D and CU users)

Figure 6 above shows the overall network throughput consisting of both D2D users and CU users. Initially, in this project we have considered 6 D2D Users and 15 CU Users. Thereafter we increase the number of Users up to 45 showing that the overall throughput of the network decreases gradually.

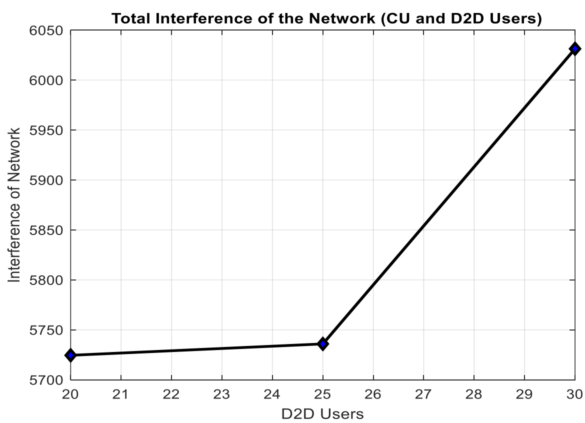

Figure 7: Total Network Interference (D2D and CU users)

Above Figure 7 shows the total interference of the network. When D2D send request for resource block allocation then BS allocate the same block to D2D users and CU Users, this creates interference. We have considered 15 CU Users which is fixed and we vary the D2D pairs. When d2D uses the same resource block then the total interference of the network also increases. So, after 25 Users the interference is quite high.

6. Conclusion

Resource allocation has received a lot of attention in D2D communication for 5 G network. Allocation of Contributor Resource increases network throughput. Thus we have suggested in this article a resource allocation scheme focused on the PSO algorithm for 5 G network D2D communication. Resource is allocated in this method to those D2D pairs that cause minimal interference, and its fitness feature is higher contrasted to other D2D pairs. The outcome from the simulation executes better. Extension of this work is to propose other methods of optimization that minimize interference.

References

1. X. Shen, "Device-to-device communication in 5G cellular networks," Network, IEEE, vol. 29, pp. 2-3, 2015.
2. K. Doppler, M. Rinne, C. Wijting, C. Ribeiro, and K. Hugl, “Device-todevice communication as an underlay to LTE-Advanced networks,” IEEE Commun. Mag., vol. 47, no. 12, pp. 42-49, Dec. 2009.
3. K. Doppler, et al., "Device-to-device communication as an underlay to LTE-advanced networks," Communications Magazine, IEEE, vol. 47, pp. 42-49, 2009.
4. D. Feng, et al., "Device-to-device communications under laying cellular networks," IEEE Transactions on Communications, vol. 61, pp. 3541-3551, 2013.
5. X. Lin, et al., "Spectrum sharing for device-to-device communication in cellular networks," Wireless Communications, IEEE Transactions on, vol. 13, pp. 6727- 6740, 2014.
6. W. Gong and X. Wang, "Particle Swarm Optimization Based Power Allocation Schemes of Device-to-Device Multicast Communication," Wireless personal communications, vol. 85, pp. 1261-1277, 2015.
7. M. Agiwal, et al., "Next generation 5G wireless networks:a comprehensive survey," 2016.
8. K. J. Zou, et al., "Proximity discovery for device-to-device communications over a cellular network," Communications Magazine, IEEE, vol. 52, pp. 98-107, 2014.
9. R. Zhang, et al., "Interference-aware graph based resource sharing for device-to-device communications under laying cellular networks," in Wireless Communications and Networking Conference (WCNC), 2013 IEEE, 2013, pp. 140-145.
10. A. E. Eiben and J. E. Smith, Introduction to evolutionary computing vol. 53: Springer, 2003.
11. H. Pang, et al., "Joint mode selection and resource allocation using evolutionary algorithm for device-to-device communication under laying cellular networks," Journal of communications, vol. 8, pp. 751-757, 2013.
12. D. H. Lee, K. W. Choi, W. S. Jeon, and D. J. Jeong, “Resource allocation scheme for device-to-device communication for maximizing spatial reuse,” Proc. IEEE WCNC 2013, pp. 112-117, Shanghai, China, Apr. 2013.
13. L. Su, Y. H. Ji, P. Wang, and F. Q. Liu, “Resource allocation using particle swarm optimization for the D2D communication underlay of cellular networks,” Proc. IEEE WCNC 2013, pp. 129-133, Shanghai, China, Apr. 2013.

14. Doppler, K., Yu, C.-H., Ribeiro, C.B., And Jänis, P., "Mode selection for device-to-device communication under laying an LTE-advanced network," Wireless Communications and Networking Conference (WCNC), IEEE IEEE, 1-6, 2010.
15. Jung, M., Hwang, K., And Choi, S., "Joint mode selection and power allocation scheme for power efficient device-to-device (D2D) communication," Vehicular Technology Conference (VTC Spring), IEEE 75th IEEE, 1-5, 2012.
16. Hakola, S., Chen, T., Lehtomäki, J., And Koskela, T., "Device-to-device (D2D) communication in cellular network-performance analysis of optimum and practical communication mode selection," Wireless Communications and Networking Conference (WCNC),IEEE, 1-6, 2010
17. Elsawy, H., Hossain, E., And Alouini, M.-S., "Analytical modeling of mode selection and power control for underlay D2D communication in cellular networks," Communications, IEEE Transactions on 62, 11, 4147-4161, 2014.
18. Da Silva, J.M.B., Maciel, T.F., Batista, R.L., And Cavalcanti, F.R.P.,"UE grouping and mode selection for D2D communications under laying a multicellular wireless system, "Wireless Communications and Networking Conference Workshops (WCNCW), IEEE, 230-235,2014
19. Cho, B., Koufos, K., And Jantti, R., "Spectrumal location and mode selection for overlay D2D using carrier sensing threshold," Cognitive Radio Oriented Wireless Networks and Communications(CROWNCOM), 2014 9th International Conference on IEEE, 26-31.2014
20. Yu, C.-H., Tirkkonen, O., Doppler, K., And Ribeiro, C., "On the performance of device-to-device underlay communication with simple power control."Vehicular Technology Conference, 2009.VTC Spring 2009. IEEE69th IEEE, 1-5, 2009
21. Liu, Z., Peng, T., Lu, Q., And Wang, W., "Transmission capacity of D2D communication under heterogeneous networks with dual bands. In Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM), 7thInternational ICST Conference on IEEE, 169-174, 2012.
22. H. Wang and X. Chu, "Distance-constrained resource-sharing criteria for device-to-device communications under laying cellular networks," Electron. Lett., vol. 48, no. 9, p. 528, 2012.
23. I. Alqerm and B. Shihada, "Energy-efficient power allocation in multitier 5G networks using enhanced online learning," IEEE Trans. Veh. Technol., vol. 66, no. 12, pp. 11086–11097, 2017.
24. R. Zhang, X. Cheng, L. Yang, and B. Jiao, "Interference graph-based resource allocation (InGRA) for D2D communications under laying cellular networks," IEEE Trans. Veh. Technol., vol. 64, no. 8, pp. 3844–3850, 2015.
25. J. R. Bhat, J. P. Sheu, and W. K. Hon, "Resource Allocation Schemes for Revenue Maximization in Multicast D2D Networks," IEEE Access, vol. 5, pp. 26340–26353, 2017.
26. H. Zhang, L. Song, Y. Li, and G. Y. Li, "Hypergraph Theory: Applications in 5G Heterogeneous Ultra-Dense Networks," IEEE Commun. Mag., vol. 55, no. 12, pp. 70–76, 2017.
27. J. Kennedy and R. Eberhart, "Particle swarm optimization," in Proc. IEEEInt. Conf. Neural Netw., , vol. 4, pp. 1942–1948, 1995.
28. Clerc, M., "Standard Particle Swarm Optimisation". HAL open access archive, 2012.