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SWARM OPTIMIZATION BASED RADIO RESOURCES ALLOCATION FOR DENSE D2D COMMUNICATION

SVMG Phani Kumar c[1] , V. Keerthi Priya[2] , K. Krishnaveni[3], M. Kusuma[4]
[1]Department of ECE, Bhoj Reddy Engineering College for Women, Hyderabad, India
[2,3,4,]UG scholar students Department of ECE, Bhoj Reddy Engineering College for Women, Hyderabad, India

Abstract

In Device to Device (D2D) communication two or more devices communicate directly with each other in the inband cellular network. It enhances the spectral efficiency due to cellular radio resources (RR) are shared among the cellular users and D2D users. If the RR sharing is not legitimate properly, it causes interference and inefficient use. Therefore, management of RR between cellular users and D2D users is required to control the interference and inefficient use of RR. In D2D enabled cellular network, D2D users have a good signal to noise ratio (SNR) compared with cellular users due to the short distances and dedicated path. Usually, solving such a problem is challenging and requires specific methods due to the major shortcomings of the traditional approaches, such as exponential computation complexity of global optimization, no performance optimality guarantee of heuristic schemes, and large training time and generating a standard dataset of machine learning based approaches. Whale optimization algorithm (WOA) has recently gained the attention of the research community as an efficient method to solve a variety of optimization problems. As an alternative to the existing methods, our main goal in this article is to study the applicability of WOA to solve resource allocation problems in wireless networks. First, we present the fundamental backgrounds and the binary version of the WOA as well as introducing a penalty method to handle optimization constraints. Then, we demonstrate three examples of WOA to resource allocation in wireless networks, including power allocation for energy-and-spectral efficiency tradeoff in wireless interference networks, power allocation for secure throughput maximization, and mobile edge computation offloading. The algorithm determines the required RR on the request of D2D users following the indicator variable. It enhances the capacity (Bit/Hz), overall system throughput and spectral efficiency with respect to sub-carriers in OFDMA networks. The performance of the proposed algorithm is evaluated via MATLAB.

Introduction

The Device to Device (D2D) communication in fourth generation long-term evolution (4G LTE) focuses on public safety, but the potential advancements that can be given by D2D operation are not completely exploited yet. D2D communication as an underlay to cellular system is viewed as one of the key advances for improving the performance of upcoming cellular systems. In 5G systems, it is anticipated that D2D operation will be locally coordinated as a component without bounds the 5G system. The fundamental potential gains by D2D including, capacity and throughput, low latency, availability and reliability and proximity services. All these gains can be achieved only using efficiently resources allocation and utilization. Collectively it is called radio resources (RR) allocation for D2D communication. In a cellular system, multiple devices exist with multiple services and operators. When many devices qualify for D2D, then who will provide the resources to accomplish D2D communication. It includes data channel, control channel and other cellular services without affecting the cellular users. The RR allocation in OFDMA cellular network has three scenarios i) cellular users to D2D users ii) D2D users to cellular users iii) D2D users to D2D users as presented in Fig.1.1.

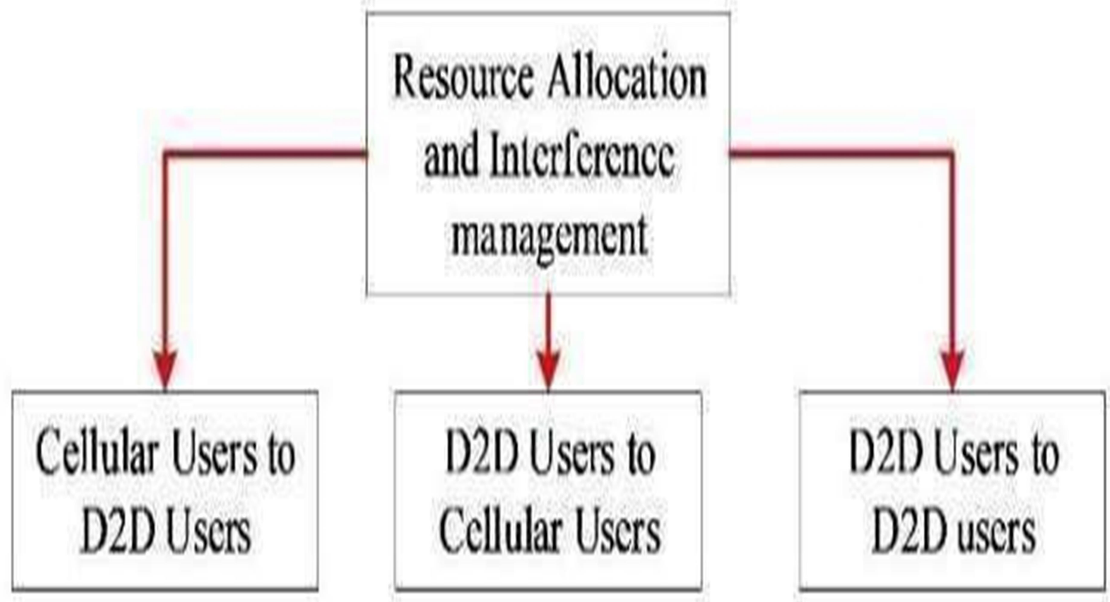

Fig. 1 Scenarios for radio resources allocation among D2D users and cellular users in the cellular system.

The fundamental thought of D2D communication is that suitable selected devices reuse the cellular resources to set up direct communication links. Given conditions are that the D2D communication does not put an adverse effect on cellular users like interference and cellular users have right to use the resources freely. Despite its awesome potential in coverage and capacity, it has some challenges particularly RR allocation. The essential thought is to reuse cellular resources by enabling adjacent wireless devices to build up direct communication links. This idea does not just enhance the proficiency of spectrum utilization, yet additionally has an extraordinary potential for upgrading the system performance articulated in terms of system capacity, throughput, spectral efficiency, and end-to-end delays. There are two approaches for RR allocation: half duplex and full duplex. Conventionally a user equipment is equipped with a single antenna, therefore two orthogonal time stages are needed for individual transmission and reception in half-duplex. In first time stage, all users' equipment should keep silent and listen from the base station on the downlink channel. In second time stage each device request for resources as cellular users or D2D users. Although this approach will not cause interference between cellular users and D2D users while degrading the RR reuse gain. To overcome this deficiency, full duplex OFDMA is an alternative and allows multi-users to use the same RR simultaneously.

To organize the system controlled D2D communication as an underlay to the cellular system, a network planner faces few difficulties, which mostly arise because of the absence of consistent channel information at the base stations. Efficient feedback is significant to get channel information. The channel information for cellular users at the serving base station can be acquired efficiently. Conversely, such information is not accessible for D2D channels. The reason is the division of the control plane from user/data plane because of the system controlled D2D communication. A quick outcome of this division is that D2D users can't specifically use pilot signals communicated by the base station in contrast to cellular users for estimation of D2D channels. Additionally, local transmission of the individual pilot signal by every D2D users is not possible and would not tackle the issue because of pilot contamination. Since techniques for overwhelming pilot contamination in D2D scenarios experience the ill effects of the requirement for expanded feedback and control overhead. Various formulations have been proposed for RR allocation, for example, proportional and max-min fairness, inelastic traffic, weighted fair queuing and convex optimization techniques.

D2D and RR allocation both are state of art and future research challenges. The emphasis is on D2D situations, for example, situations with normally low mobility where data offloading, improvement of network capacity, reduced latency and enhance data rates play a leading role.

The attention will be on in-band underlay D2D communication, in which D2D utilizes similar resources of the spectrum from the cellular network. It is sensible to expect that RR allocation to D2D users must be accomplished in a distributed manner under entirely restricted channel information. In addition, it is of most extreme significant that immediate transmissions among devices are coordinated to guarantee that they don't detrimentally affect the performance of cellular users. Such coordination must include a cautious power allocation of D2D users to available RR, essentially utilized as downlink or uplink. This issue, which is hard to understand even in a centrally controlled system, is additionally provoked in a D2D setting by the requirement for distributed arrangements. Therefore, RR allocation model for multi-devices in OFDMA system is proposed for high data rate, energy efficiency and interference avoidance between cellular users and D2D users. With the D2D pair establishment, RR can be allocated to that pair for communication. After discovery, as discovered device receives a request for connection, RR is thus allocated to discoverer devices only. It allows the D2D pair to transmit and receive data over the same allocated channel. Swarm optimization is applied for RR allocation to minimize the interference between cellular users and D2D users. It enhances the system capacity, throughput, and frequency efficiency.

Literature Survey

Device-to-Device Communications :

Device-to-Device (D2D) communication is one of the key features of 5G networks. This concept refers to the ability of the user terminals to communicate directly in a peer-to-peer manner without the need to pass through an access point. Historically, the idea of exploiting peer-to-peer communications within cellular networks is not new. However, it is only recently that D2D has been considered to be integrated into the next generation networks.a distinct feature of D2D, when employed in cellular networks, is that infrastructure is involved in the assistance and coordination of the D2D control functions (e.g., resource allocation, routing, synchronization, session establishment, and authentication). Figure 2.1 also shows the three possible operation scenarios regarding the cellular coverage. Namely, i) In-Coverage Scenario, ii) Partial-Coverage Scenario, and iii) Out-of-Coverage Scenario.

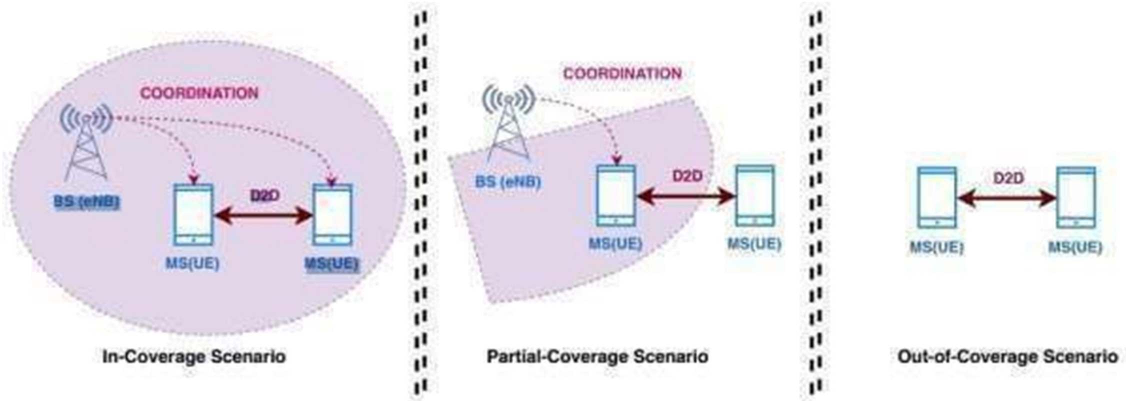

Figure 2 – D2D inside a cellular network: coverage scenarios

3GPP introduced D2D within LTE-A architecture in 3GPP Release 12 as an enabler for Proximity Services (ProSe) which included two essential functions: i) direct discovery, and ii) direct communication between (enhanced) UserEquipments (UEs). The primary motivation behind this LTE-D2D standard, aka LTE-Direct, is to provide competitive wireless technology for public safety networks to be used by first responders. In addition to public safety applications, 3GPP ProSe supports discovery-based services for commercial use cases and network coverage extension using UE-to-Network relay. Figure 2.2 shows the evolution of the D2D support in the 3GPP standards. In 3GPP Release 13, LTE- D2D improved the ProSe support for various scenarios including inter-operator and out-of-coverage scenarios. A significant enhancement in the standard was introduced in Release 14. It consists of supporting Vehicle-to-Everything (V2X) communications. In Release 15, which represents the first phase of 5G, the support for IoT and Wearables was included in the LTE-D2D. In fact, it was decided that IoT and wearable devices would benefit from short D2D links and optimized UEtoNetwork relays through cooperating UEs, to extend their battery life. In Release 16, the support for V2X was further enhanced.

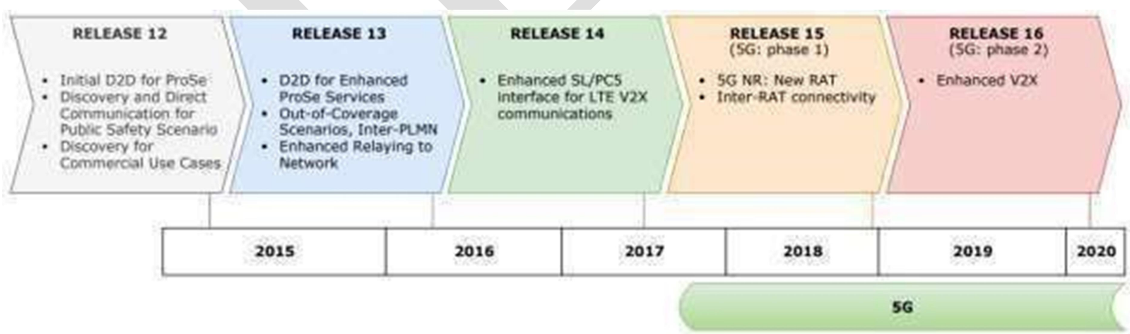

Figure 3– State of the D2D support in LTE releases

Device-To-Device Communication in 5G Environment

New technologies fundamentally change the way people exchange information with each other, especially in wireless communication and mobile computing. Despite this, cellular mobile environment is still infrastructure-dependent. The mobile users connection is restricted depending on the base station (BS) coverage, and does not permit direct communication among mobile devices. Even though the source and the destination are in close proximity to each other, the routing traffic is routed through the core network. Due to this inability, the possibility of exchanging data among mobile users is limited, especially considering the transformation process of personal computing from desktop computers to laptops and finally to mobile devices. Due to the trend of shifting toward mobile devices, the traffic for mobile data is expected to increase to 30.6 exabytes per month by 2020, estimated an eight-time increment over 2015. One of the benefits derived from D2D is content privacy and strong anonymity. These are provided because the central storage is not responsible for storing the shared information. D2D communications also have the potential to improve energy efficiency, throughput, fairness, and delay. Furthermore, by enhancing the system throughput and spectrum reusage due to the D2D traffic direct routing, the performance of D2D improves significantly. D2D offloads the cellular traffic by switching the path from infrastructures to direct transmissions. These attributes produce low transmission delay, energy savings, and a high data rate. Standalone D2D is one the drawbacks of D2D because it only uses links that are managed by devices where there is no possibility of channel management and centralized relay, whereas for network-assisted D2D, the BS, together with the help of operator-controlled links, can only partially maintain channel selections and relay. Thus, in-depth research attention is needed to manage the interference in D2D communication.

PROPOSED METHODOLOGY

In our problem, we have to maximize the system throughput by optimally sharing the cellular resource units to the D2D pairs. In our system, we have C number of CUs and D number of D2D pairs. In our objective function, cd represents the resource units assignment variable.□
So, we have to optimally distribute the C number of spectrum resources to the D number of D2D users such that the network throughput can be maximized. Optimal distribution of C number of spectrum resource to the D number of D2D users where same cellular spectrum resource can be shared by more than one D2D pair can be considered as permutation problem. But finding system throughput for all the possible permutations will increase computational complexity as well as latency to the system. So, we have to find the optimal solution by converting it into an optimization problem. In (Hu, X., Eberhart, R.C., & Shi, Y., 2003), the authors have proposed a modified particle swarm optimization method for permutation optimization, which can be used for our problem. PSO Algorithm Our problem is basically a permutation problem, where we have to find the optimal permutation of the resources that will maximize the network throughput. A permutation problem is nothing but a constraint satisfaction problem, where each variable holds a unique value. When a permutation satisfies all the constraints, it is called a feasible solution.

RR Allocation Techniques For D2D Users

There are two types of RR allocation techniques in in-band D2D communication: underlay and overlay as described in fig 6.1. The expansion of the D2D layer as an underlay to cellular systems postures new difficulties in term of interference control compare with ordinary cellular networks. RR allocation for D2D in underlay cellular network is proposed based on joint scheduling. It controls the power to avoid the interference and maintain the QoS of D2D link, but the problem is accommodation of maximum users is quite difficult. RR

allocation in mobility structure for underlay D2D is presented in in which, RR are apportioned based on distance. When the distance is increased, channel allocation becomes problematic between D2D pair. A distance limit model for RR allocation is proposed in, in which RR are allocated cellular and D2D link based max-flow algorithm. It enhances the sum rate but creates
interference. These difficulties originate from the reuse of radio resources among cellular users and D2D users, which make intra-cell interference.

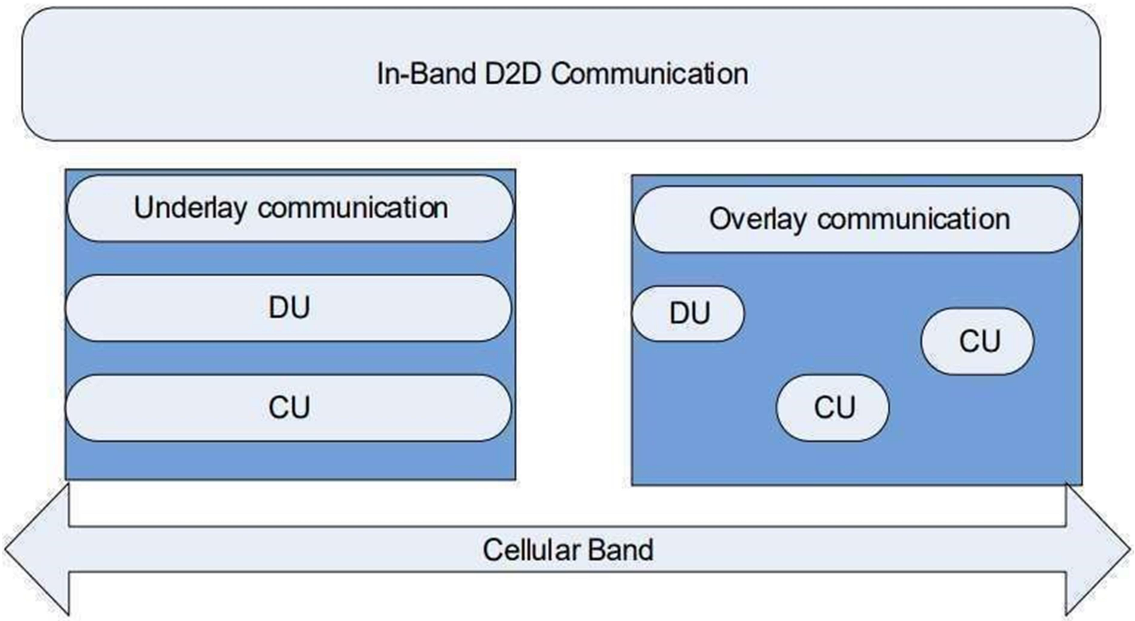

Fig.4. In-band D2D radio resource distribution as an underlay and overlay.

Consequently, to exploit the advantages of D2D communication and accomplish an enhanced network performance over standard cellular networks, cautious RR allocation that considers both cellular users and D2D users is fundamental. RR allocation procedures for D2D underlay communication can be ordered relying upon the optimization metric. RR allocation figures out which particular frequency and time resources ought to be allotted to each D2D and cellular links. RR allocation algorithms can be comprehensively grouped by the level of system control, centralized versus distributed, and the level of coordination between cells, single cell versus multi-cell. Every cellular user in OFDMA is allocated to the sub-carriers and every subcarrier is allocated by the network. To facilitate an essential unit of RR allocation in OFDMA, subcarriers are characterized as a sub-channel. Contingent upon how the subcarriers are allocated to build each sub-channel.
The RR allocation techniques are grouped into a random type, comb type and block type as is appeared in Fig. 6.2. To avoid the wastage of RR, random type RR allocation is considered in this research. In a random type RR allocation, each sub-channel is comprised of a set of subcarriers allocated randomly over the whole spectrum. If random type sub-channels are utilized, then interference is incorporated to accomplish the adversity gain. For this situation, all pilots situated over the entire bandwidth might be utilized for channel estimation between cellular users and D2D users. This sort of sub-channels tends to normal out the channel quality over the entire band. Therefore, it can oblige high mobility, anyhow, when the quality of each subcarrier consistently differs

from one frame to the next. In a D2D enabled cellular network, besides, it is helpful for decreasing the co-channel interference by haphazardly allocating subcarriers such that the probability of sub-carrier interference among D2D users and cellular users decreases. In random type RR allocation, to avoid the interference between co-cells different random type allocation is performed as presented in Fig. 3 random type(a) and random type(b). In this research in-band underlay, RR resource allocation technique is considered. The RR allocation is generic and can be pragmatic to many systems for example, multi-cast, ad-hoc and Wi-Fi network. Therefore, some successful solution is required for D2D communication enabled network in which optimization is required to minimize with delay and interference.

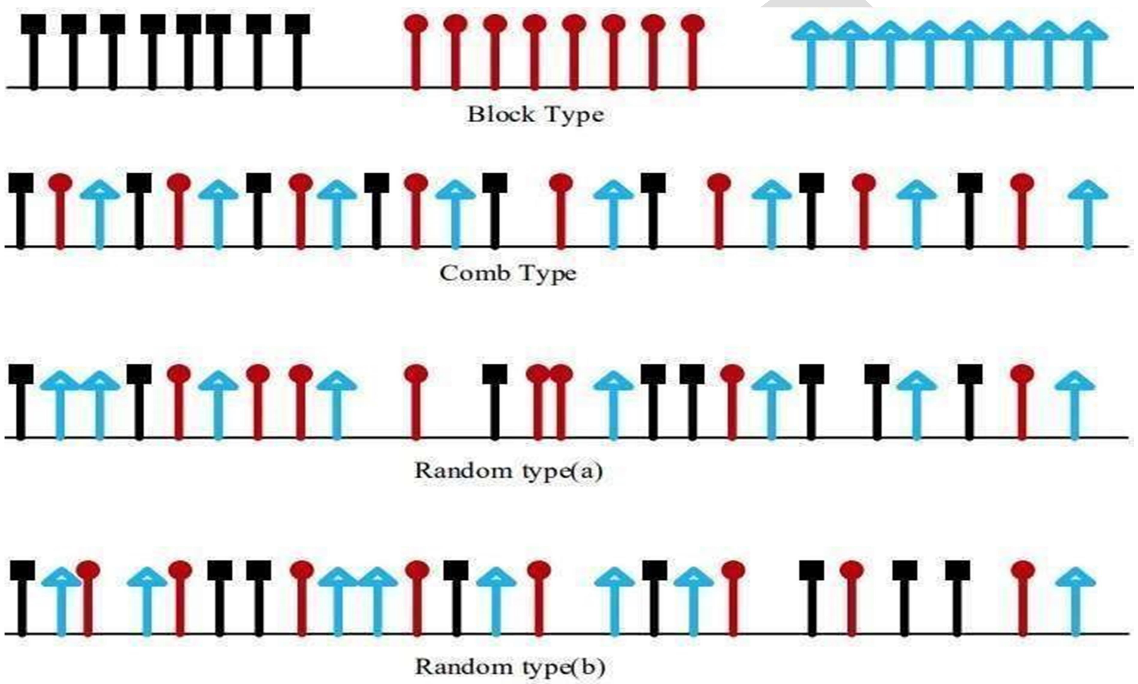

Fig. 5. In-band D2D radio resource distribution as an underlay and overlay.

In simple terms, in-band D2D (Device-to-Device) radio distribution refers to the transmission of data between devices using the same frequency band as cellular networks. It can be used as both an underlay and overlay. As an underlay, D2D communication operates alongside the existing cellular network, allowing devices to directly communicate with each other without going through the base station. This can improve network capacity, reduce latency, and enable new services like proximity-based applications. On the other hand, as an overlay, D2D communication uses a separate channel within the existing cellular network to establish direct connections between devices. This allows for more efficient resource allocation, improved coverage, and better user experience. Overall, in-band D2D radio distribution offers exciting possibilities for enhancing communication efficiency and enabling new applications.

RESULTS

The graph above mentioned would likely show how the transmitter power required by D2D devices changes as the distance to the base station varies. It can help optimize resource allocation and ensure efficient

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communication in dense device environments. The x-axis would represent the distance to the BS in meters, while the y-axis would indicate the transmitter power in a suitable unit, such as decibels (dB).

By using PSO, the algorithm would dynamically allocate the transmitter power based on the distance between the devices and the base station. As the distance increases, the transmitter power required for reliable communication might also increase to overcome signal attenuation and maintain a satisfactory link quality. The graph would demonstrate how the transmitter power changes with varying distances, allowing for optimization of radio resource allocation. This optimization aims to minimize power consumption, reduce interference, and ensure efficient communication in dense device environments.

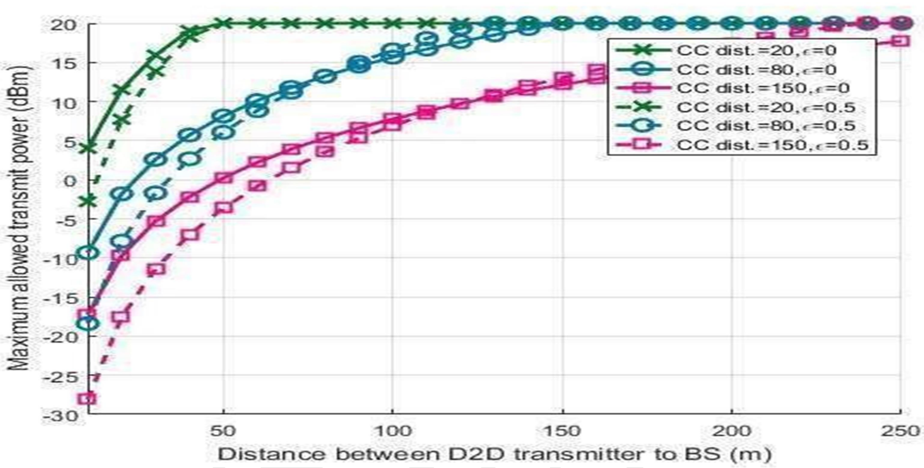

Fig 6 Transmitted power Vs Distance to the BS(m) with PSO

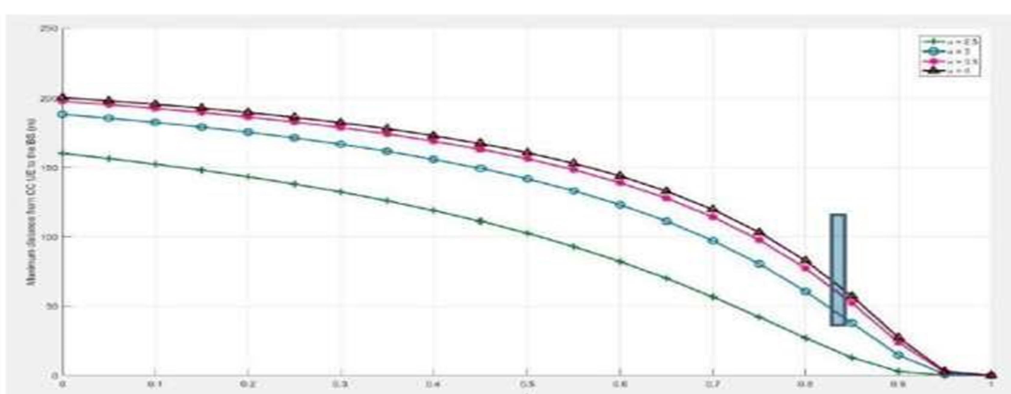

Fig shows the maximum distance from CCUE to the BS(m) with pso

Fig 7 Maximum Distance from the CCUE to the BS (m) with PSO

This graph would illustrate the relationship between the maximum distance a CCUE(communication capable user equipment) can be located from the BS. The x-axis would represent the maximum distance from the CCUE to the BS in meters, while the y-axis would indicate the performance metric, such as signal quality or throughput. The PSO algorithm would be utilized to dynamically allocate radio resources and optimize the communication between CCUEs and the BS. By varying the maximum distance from the CCUE to the BS, the graph would demonstrate how the PSO algorithm adapts and performs in different scenarios. It would provide valuable insights into the trade-off between the maximum distance and the performance of the PSO algorithm. It would help determine the optimal range within which
CCUEs can be located from the BS to achieve reliable and efficient D2D communication.

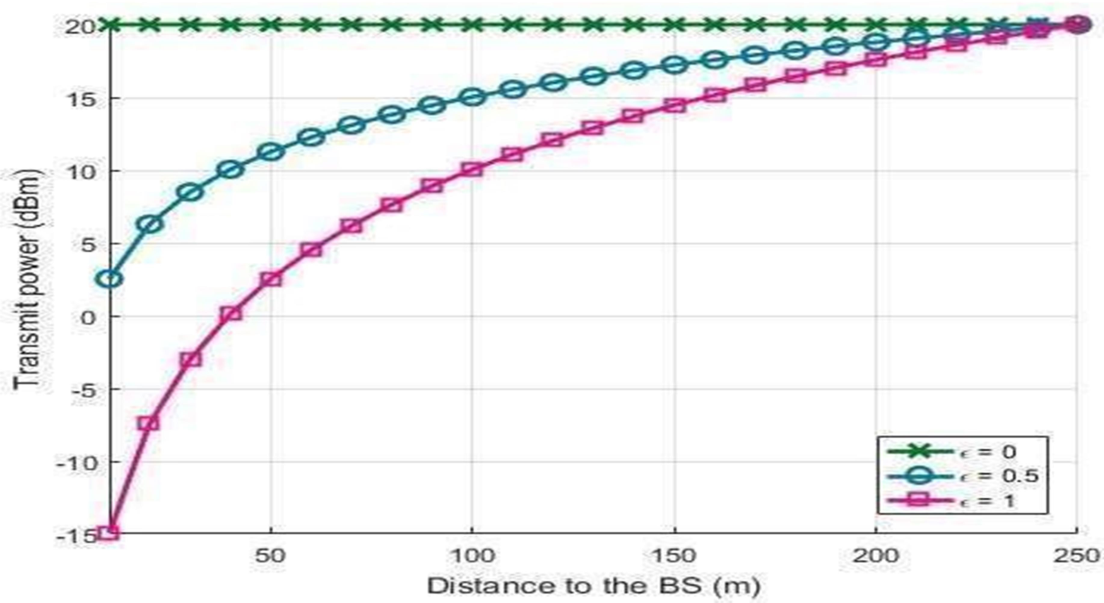

Fig 8 Fitness Value Vs Number of iterations (m) with PSO.

This graph would illustrate how the fitness value, which represents the quality or effectiveness of the radio resource allocation, changes over the course of the PSO algorithm iterations. The x-axis would represent the number of iterations (m), indicating the progress of the algorithm, while the y-axis would indicate the fitness value. The fitness value in this context could be a metric that quantifies the performance of the radio resource allocation, such as signal quality, throughput, or another relevant metric. The fitness value is typically calculated based on the objective function or optimization criteria used in the PSO algorithm. By plotting the fitness value against the number of iterations, the graph would provide insights into how the PSO algorithm converges and improves the radio resource allocation over time. It can help determine

whether the algorithm is effectively optimizing the allocation of resources for D2D communication in dense device environments. Analyzing this graph can provide valuable information about the convergence behavior of the PSO algorithm and help assess its
performance in achieving optimal radio resource allocation.

Whale Optimization Results :

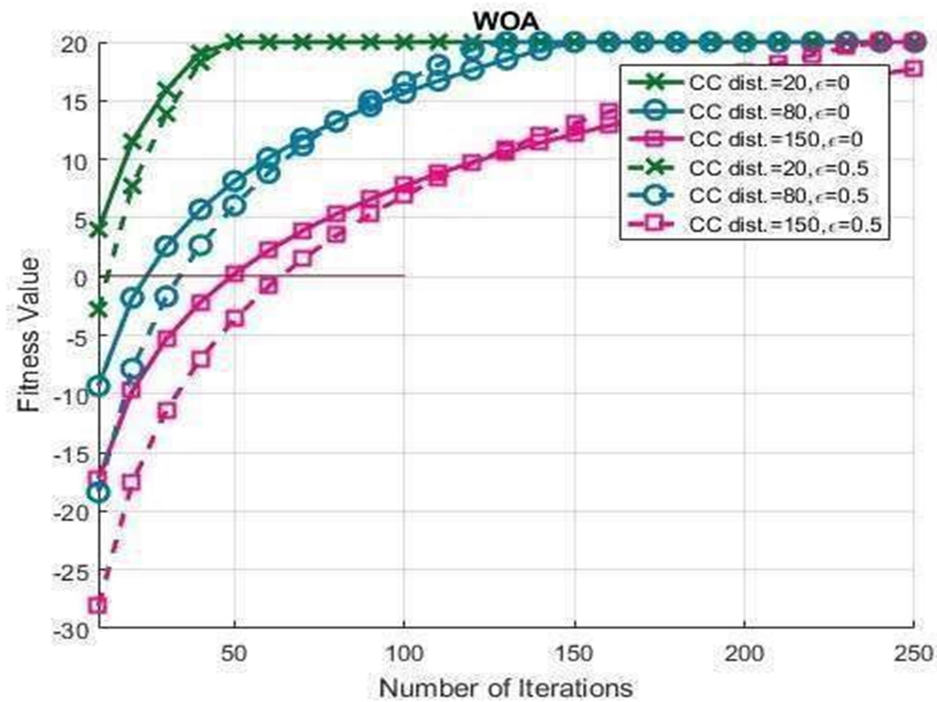

Fig 9 Fitness Value Vs Number of iterations (m)

Similar to the PSO algorithm, the graph shows how the fitness value, representing the quality or effectiveness of the radio resource allocation, changes as the WOA algorithm progresses through iterations. The x-axis represents the number of iterations (m), indicating the progress of the algorithm, while the y-axis represents the fitness value. The fitness value, in this case, is a metric that quantifies the performance of the radio resource allocation, such as signal quality, throughput, or another relevant measure. By analyzing the graph we can gain insights into how the WOA algorithm converges and improves the radio resource allocation over time. This graph helps us understand whether the algorithm effectively optimizes the allocation of resources for D2D communication in dense device environments. Studying this graph provides valuable information about the convergence behavior of the WOA algorithm and helps evaluate its performance in achieving optimal radio resource allocation.

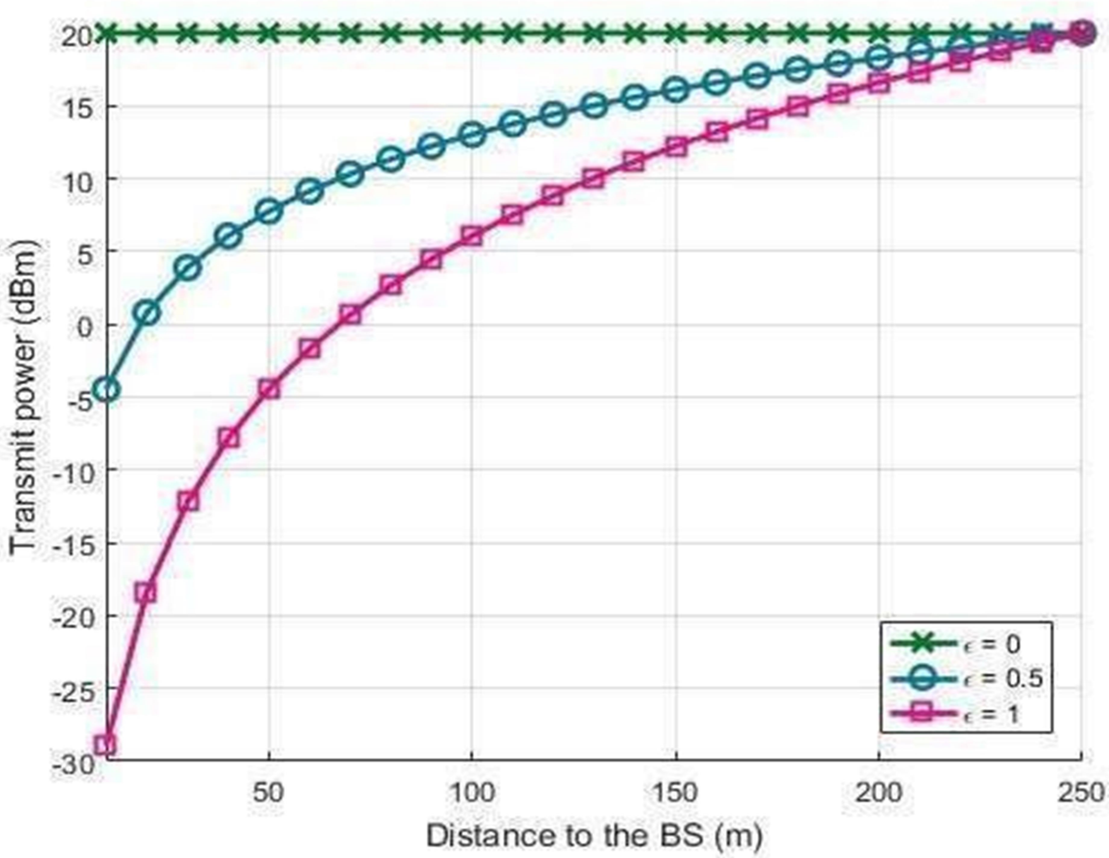

Fig 9 Transmitted power Vs Distance to the BS(m) with WOA

This graph shows how the transmitted power changes as the distance to the BS varies. The xaxis represents the distance to the BS in meters, while the y-axis represents the transmitted power. The transmitted power refers to the amount of power used by the devices in D2D
communication to establish a connection with the BS. It is an important parameter as it affects the signal strength, coverage, and overall performance of the communication system. By analyzing the graph of transmitted power versus distance to the BS, we can observe how the power requirements change as the devices move closer or farther away from the BS. This information helps in understanding the power allocation strategy and optimizing the power usage for effective D2D communication in dense device environments. Studying this graph provides insights into the relationship between the distance to the BS and the transmitted power, enabling us to make informed decisions regarding power management and resource allocation.

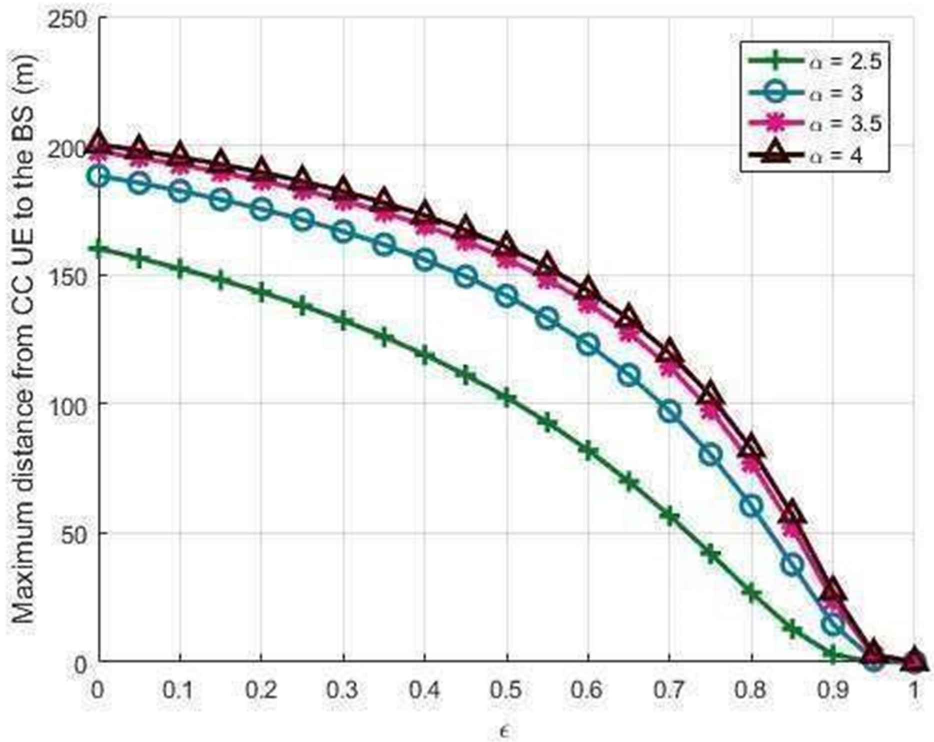

Fig 10 Maximum Distance from the CCUE to the BS (m) with WOA

CONCLUSION & FUTURE SCOPE

After device discovery in D2D communication, resource allocation is the major issue to avoid the interference. the Particle Swarm Optimization (PSO) algorithm plays a crucial role in the project by utilizing PSO, we can effectively allocate radio resources in dense device environments, optimizing communication efficiency and resource utilization. The PSO

algorithm's ability to explore and exploit the search space enables us to find optimal solutions for radio resource allocation, ensuring reliable and efficient D2D communication. With further research and development, the PSO algorithm can continue to drive advancements in optimizing radio resource allocation for dense device scenarios, ultimately enhancing the overall performance and user experience. It enhances the system capacity, frequency efficiency, and throughput. We have presented the fundamentals of the whale optimization algorithm (WOA) and its applications to resource allocation in wireless and communication networks. Since the application of WOA to wireless and communication networks remain unexplored and the WOA-based algorithm can provide the competitive performance compared with the stateofthe-art algorithms, WOA can be used as a benchmark for performance comparison when someone proposes his own methods for any optimization problem. We hope that this paper will be serving as a starting reference for the adoption of WOA in optimizing resource allocation in wireless networks as well as other engineering branches. Further, this work can be extended for scheduling between cellular users and D2D users.

The future scope of the project is quite promising. One potential area of focus is the development of advanced algorithms that combine swarm optimization with machine learning techniques to further enhance the efficiency and reliability of radio resource allocation in dense device environments. Additionally, exploring the integration of this approach with emerging technologies such as 5G networks, IoT, edge computing, and green communication practices could open up new possibilities for optimizing D2D communication. By delving deeper into these areas, we can continue to improve the performance and effectiveness of resource allocation in dense device scenarios, paving the way for more efficient and seamless communication experiences

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