Ant ColonyPerformance Evaluation and Optimization–based Resource Allocation for D2D Communication

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Abstract

In the fifth generation (5G), it is anticipated that device-to-device (D2D) operation will be locally incorporated as a part without any bounds. In Device-to-Device D2D network, Device-to-Device (D2D) communication recently has been developed as a new paradigm that supports spectrum reuse inside a cell, and enhancement quality of service (QoS) and leading to expert user experience. Spectrum allocation problem is an important part in the study of D2D communication and represent an open challenges in the spectrum allocation under D2D communication scenario. The resource allocation for D2D design consider the best solution towards this challenge. In this paper, we propose a D2D in which the resource allocation problem is formulated. Then, a resource allocation scheme based on Ant Colony Optimization (ACO) algorithm. . Finally, ACO is considered best solution oriented to identifying interference and establishing D2D links that can optimizing the same resources, consulting a graph representation of the network. Simulation using matlabtool studies and show self-learning nature , which results to a comparable performance to that of an optimal resource allocator. The swarm intelligence algorithm ACO, is adopted to resolve the optimization problem of maximizing the network sum rate while considering the QoS requirements.

Keywords *— Device-to-Device; Ant Colony Optimization; Spectrum allocation; resource allocation; spatial spectrum reuse; QoS requirements; LTE-Advanced*

I. INTRODUCTION

Device-to-Device (D2D) communication is the basics technology oriented towards 5G and and is supposed as an component 4G-Advanced (LTE-A) network . It point to the scheme where two C-UEs or V2Xs communicate directly with each other, by passing the base station. Among its multiple advantages, D2D promises to enhance the end-users' experience, by reducing the communication latency and energy consumption, while, from an operator's perspective, it contributes towards network offloading and spectrum reuse [1].

Device-to-Device (D2D) communication is classified as showed in Fig.(1) based on the of spectrum type used, we refer to *inband*and *outband*D2D, licensed and unlicensed spectrum, which can useful for utilization as data transmission respectively [2]. Above that , D2D may classified as an *underlay* to the normal cellular process and we reuse the resources with normal cellular users, the *overlay* mode, where their resources are either is assigned exclusively for D2D process. As regards for the control of the process in the D2D procedure, we find *autonomous* and *controlled* schemes. Above that, as regards for initiation of the D2D communication request, there are two alternative either the D2D request is fully transmit to the end-user communication is automatically switched from cellular to D2D mode by the operator (network originated), or the D2D mode is originally (explicitly) required by the user). Finally, D2D transmissions may be *unicast* or *multicast/broadcast*, where the former case describes peer-to-peer links for direct communication or relaying links (e.g., for coverage extension purposes), while the latter would be more appealing for social and commercial applications, such as proximity-based advertisement or public safety scenarios.

In Figure 1, with the classification above, we illustrate the D2D communication scenario currently under consideration (gray boxes). Specifically, we focus on overlapping and overlapping bandwidth links and a single-user and user-controlled single-serving message. The base station operator is the entity responsible for allocating resources for these D2D connections.

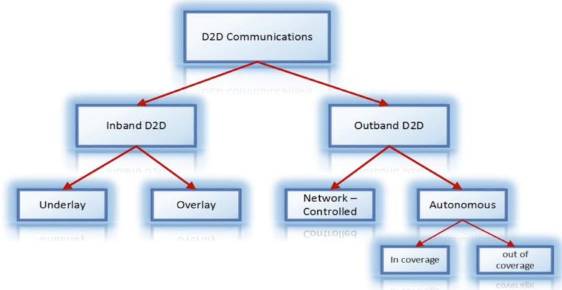

Fig.1. Classification of D2D communication

A diversity of resource allocation procedures for D2D communications can be remembered in details [3, 4]. The majority of them adopt the basis for proposing plans that ensure low levels of interference in the reception of cellular and D2D mode. However, co-existence is free of D2D and cellular communication is a very difficult task, leading to limited re-use of spatial spectrum. So overlay mode undertaking a lot of number of D2D links without making any difference for the cellular communications. In both sides, proposed solutions let resource allocation schemes where interference or topology information is available at the base station [4, 5]. Within this perspective, the effective way of representing the information of the overlapping topology is in a graph, as shown in [6, 7].

Capitalizing on this idea, we study the problem of D2D resource allocation in LTE-A networks, targeting at minimizing the amount of spectrum required for serving a specific number of overlaying D2D requests. The proposed scheme exploits the Ant Colony Optimization (ACO) theory and a graph representation of D2D mutual interferences, as a means to guarantee multiple concurrent D2D transmissions with specific target outage probability.

The remainder of this paper is organized as follows. In Section II, the considered system model is presented and the problem under study is expressed using a network graph representation. Section III describes the ACO terminology and algorithmic logic for solving this problem, while Section IV contains evaluation results using simulation. Finally, Section V concludes the paper.

II. SYSTEM MODEL

In a statement this problem, we consider a network with LTE-A allow D2D connection. LTE-A is referred to as the developed NodeB (eNB) and to the end-user cellular as User Equipment (UE). eNB is not responsible for allocating spectrum resources for UES systems for each 1 ms schedule, known as the TTI as shown in Figure (2). With respect to the resource allocation procedure, the available spectrum is divided into allocation units referred to as Resource Blocks (RBs).

Outage probability of a communication channel is the probability that a given information rate is not supported, because of variable channel capacity. Outage probability is defined as the probability that information rate is less than the required threshold information rate. It is the probability that an outage will occur within a specified time period. Slow-fading channel for example, the channel capacity for slow-fading channel is $C = \log_2(1 + h^2 \text{ SNR})$, where h is the fading coefficient and SNR is a signal to noise ratio without fading. As C is random, no constant rate is available. There may be a chance that information rate may go below to required threshold level. For slow fading channel, outage probability = $P(C < r) = P(\log_2(1 + h^2 \text{ SNR}) < r)$, where r is the required threshold information rate [11].

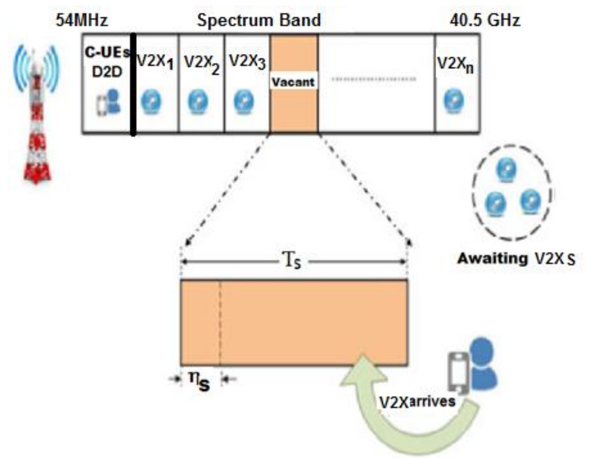

Fig (2) D2D activity model and VX2 occupancy in the given spectrum

After the scheduling process, a number of D2D requests are assigned for transmitting in a specific TTI. Sequentially, per TTI, a resource allocator decides on how many and which RBs will be used by each one of the scheduled D2D requests. The major challenge for the resource allocator is to exploit current spatial spectrum reuse opportunities towards minimizing the number of RBs required for satisfying all D2D requests.

The spatial reuse of the same RBs by multiple D2D pairs may be possible due to the low range of the D2D transmissions. To elaborate on this, we illustrate in figure (2) the case where a specific spectrum portion is utilized by uniformly distributed D2D transmitters in a cell (Fig. 2a). All D2D users use fixed transmit powers that enable short-distance D2D links. Under this deployment, the summated signal strength in each grid point of the cell area is depicted in Fig. 2b, identifying the feasibility of spatially reusing the spectrum multiple times in the cell area (locally-restricted interference is observed).

Let D be the number of D2D requests scheduled in a specific TTI. To *minimize* the spectrum resources required for serving those requests, the eNB should estimate the *maximum* number of parallel D2D transmissions that can concurrently use a specific spectrum portion. In other words, the problem under consideration is the following: *For a specific set of D2D requests (D) find the largest subset (L) that may spatially reuse the same spectrum portion under constrained interference conditions, which ensure acceptable quality for the D2D links.*

For instance, given the topology of figure (3), where totally twenty D2D requests are present ($D1 = 20$), the largest subset found is $L1 = 10$. Hence, ten transmissions (solid links) may safely reuse the same spectrum portion.

A. Graph representation of D2D interferences

First we represent matlabcode to creates an illustration of interchange interference cases through cooperative D2D wireless road , representing a linked weighted between the nodes on the arcs. The representation is construct up on information obtained by the UEs to the eNB. specially, all UEs notify information about the received information due to any potential parallel D2D transmission (i.e., interference). When obtained this interference information by the UEs, this may be by using the D2D peer discovery procedure. As in figure (5, 6) theeNB turn the information of the obtained interference values to the graph.

Let $G = (V, E)$ be a graph where the vertexes represent the D2D requests: $V = \{v1, v2, \ldots, vD\}$, and the edges represent mutual interferences between any two competing requests: $E = \{(v1, v2), (v1, v3), \ldots, (v1, vD), (v2, v3), \ldots, (vD{-}1, vD)\}$. The edges are weighted and these weights represent the level of mutual interference between any two potential parallel D2D transmissions, dependent on the actual channel conditions. In order to quantify this, we introduce the *Interference Level Indicator* (*ILI*) term. *ILI* takes values according to a configurable interval scale, ranging from a minimum to a maximum value. The min/max values in this scale correspond to the min/max estimated interference in the current topology, while all in-between values are calculated uniformly. Hence, a [0-1] scale implies that interference is present or not, while a [1-100] scale is able to describe 100 distinct levels of interference. The mapping of interference values to *ILIs* is done by the eNB. Ignoring, the zero values, the produced graph is fully connected, because all vertexes are potentially able to interfere to each other, either heavily (edge weight = large *ILI*) or almost negligibly (edge weight = small *ILI*). Therefore, in this representation, the lower the weights among nodes, the less the mutual interference, and consequently, the higher the chances for a safe spectrum sharing. An example of a network graph representation is given using Matlab Tool in Figure (4) and figure (5), where nodes one through nine represent five D2D requests and *ILIs* range from 1 to 15. Here, the *ILI* between vertexes A and B is 14, implying that these parallel D2D requests are in close proximity, while between A and E it is 1, implying that these are very far from each other and probably not interfering at all.

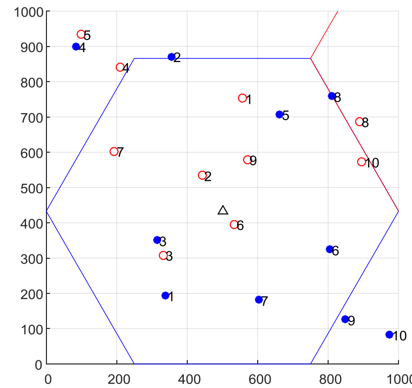

Fig. 3.D2D classification types.

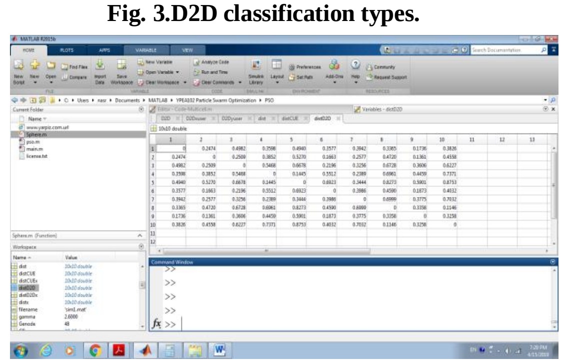

Fig. 4. Interference results between D2D nodes

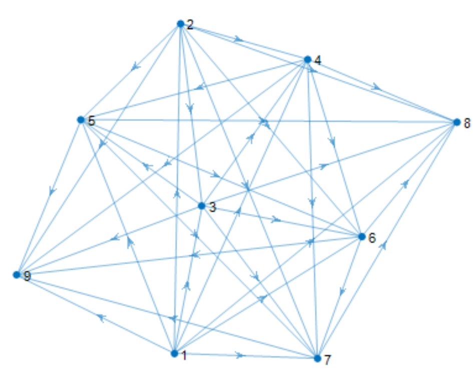

Fig (5) Interference graph of the D2D pair

B. Probability of D2D communication outage

The communication of one D2D pair is considered successful, if the receiver's Signal to Interference plus Noise Ratio (SINR) is above a pre-defined threshold, which guarantees acceptable quality; otherwise an *outage* occurs. As interference, we consider the summation of all received powers due to the rest of the D2D requests scheduled simultaneously, which belong to the same subset L. This SINR value is calculated inside the eNB for each D2D link by exploiting already available interference information. This is feasible since the eNB is already aware of the received power at one D2D receiver by any other parallel D2D transmission (information already used for the graph representation), be it either interference or the desired signal strength.

The finding of the maximum possible size of L is driven by an iterative procedure inside the eNB. Measuring the number of outages out of all the scheduled D2D requests that compose L, the eNB gets an estimation of the average Outage Probability ($Pout$), which, in turn, is compared to a maximum acceptable threshold. If $Pout$ is less than this threshold, then the selected subset will have the current size of L; otherwise, the considered size of L has to be decreased by one and the new $Pout$ has to be estimated. As for the finding of the optimal requests composing L, this is driven by the ACO procedure, described next, as an effort to avoid the exhaustive examination of all possible combinations of sets of size L.

III. ANT COLONY OPTIMIZATION

ACO for D2D resource sharing When$Llen$, i.e., the subset length is given, the optimization problem is expressed as the minimization of a sum of weights where W is a DxD matrix of all ILI weights. Thus, the problem is translated to finding which vertexes should be selected as a part of the solution L, minimizing a total cost. Here, the cost is the summated interference experienced by the D2D pairs when they share the same RBs, expressed via the summation of the respective ILI weights. It is worth noting, that the diagonal elements of the matrix W represent the channel conditions among a D2D transmitter and its target receiver (desired signal), hence they represent the quality of the D2D link.

$$\boldsymbol{min}\sum_{1}^{L_{len}} \boldsymbol{W}(\mathbf{v_1}\, \boldsymbol{v_2}), \quad \boldsymbol{where}\, \boldsymbol{v_1}, \boldsymbol{v_2} \in \boldsymbol{V}$$

Eventually, the problem of finding the vertexes composing L becomes a redefined graph coloring problem, where two adjacent nodes *can* be colored the same, if they consist part of the same solution, whereas in the traditional graph coloring problem, two adjacent nodes *cannot* be colored the same. In our scenario, when two D2D requests (vertexes) consist part of the same solution, it means that they have been allocated the same RBs (colored the same) for D2D transmission purposes.

This problem may be solved using the ACO theory. According to [8], "*The main underlying idea, loosely inspired by the behavior of real ants, is that of a parallel search over several constructive computational threads based on local problem data and on a dynamic memory structure containing information on the quality of previously obtained result*". ACO was originally designed for solving routing problems, namely, as a way to find optimum routing paths. Nevertheless, here we adopt this theory for solving a resource allocation problem using a network graph representation. The eNB is the network entity in charge of running the ACO algorithm.

Ants are treated here as "colored agents", and each one is carrying a unique color. When an ant visits a node it "paints" it with this color. In the resource allocation scenario, this means that the ant allocates the same spectrum portion (color) to all visited nodes (i.e., D2D requests), which will then consist a part of this ant's solution L. The main idea behind this ACO version is to exploit ILI awareness to estrange two D2D pairs with good mutual channel conditions (i.e., in close proximity). Overall, the redefined parameters of the ACO are:

- i, = D2D requests, or simply, the graph's vertexes V.
- n = the index of an adjacent node j, $\{j1,2,\ldots,jn,\ldots\}$.
- N = the total number of ants.
- k = the index to an ant.
- $L^k=\{vi,vj,\ldots,vLlen\}$ = the solution of each ant k.
- L_{len} = the length of this solution (subset length).
- $tabu^k$ = the "tabu list" of ant k, to prevent it from coloring the same node more than once.
- r = the evaporation rate. It represents how fast the topology changes and hence, how fast acquired knowledge by past ACO iterations fades.
- d_{ij}= the "distance" between two competing D2D requests, here equivalent to the $ILIij$ between a D2D transmitter and a victim D2D receiver (higher ILI means higher distance).
- η_{ij} = the attractiveness of moving from node i to j. It indicates the a priori desirability of the ant's next

move, i.e., here, the desirability of assigning the same color to request j, provided that it has been already allocated to i.

- $\eta_{ij} = \frac{1}{d_{ij}} = \frac{1}{ILI_{ij}}$
- C^k = the estimated cost that derives from ant k's route. Here, it is the total ILI "experienced" by this ant, i.e., the sum of all $ILIs$ of all edges belonging to the solution of this ant. In Fig. 4, this cost would be 8+10+6, if the ant visited the nodes A-D-C-E.
- $\Delta x\tau_{ij}^k$ = the pheromone deposited by ant k's $i \rightarrow j$ move:
- $\Delta x\tau_{ij}^k = \begin{cases} \frac{1}{C^k} \text{ if both i and j were visited by ant k} \\ 0, if\ \ not \end{cases}$
- τij = the trail level or amount of pheromone deposited for moving from i to j. It indicates how proficient has been in the past the coloring of j given the same coloring of i and, thus, indicates the a posteriori desirability of this move.

$$\tau_{ij}(t) = (1-r)\tau_{ij}(t-1)\sum_{k=1}^{N} \Delta x\tau_{ij}^k$$

- α = the level of importance of τ, $1 \geq \alpha \geq 0$.
- β = the level of importance of η, $\beta \geq 1$.
- p_{ij}^k = the transition probability that ant k will move from state i to state j. It depends on both η and τ.

$$p_{ij}^k = \frac{\tau_{ij}^{\alpha}\ \eta_{ij}^{\beta}}{\sum_{all\ \ feasible\ \ j\ states}\ \tau_{ij}^{\alpha}\ \eta_{ij}^{\beta}}$$

For the purposes of evaluation, the LTE link level simulator of [9] has been exploited in order to setup the system environment with D2D communication available, as well as to reliably estimate the received signal strengths from potential parallel D2D transmissions, required as input by the ACO algorithm. For the simulation, the selected input parameters were compliant with LTE standardized values and ACO recommendations [10], as depicted in Table I.

Initially, we demonstrate an example to assess the number of iterations needed for the ACO to reach a close-to-optimal solution. We allow the algorithm to run locally at the eNB for multiple evaluation runs (x axis in Figure (5)), and we observe the algorithm's behavior in terms of reducing the total cost, which corresponds to the sum of $ILIs$ across D2D connections sharing the same resources (y axis in Figure (5)). As it can be observed in Fig. 5, the algorithm gradually approaches a stable solution, due to its self-learning nature. Starting from a reference cost of 110 units (dashed straight line), the algorithm manages to steadily reduce the total cost down to around 25 units. This reduction indicates the discovery of constantly better paths, or equivalently, the discovery of constantly better combinations of D2D requests that are more likely not to interfere with each other when sharing the same spectrum portion.

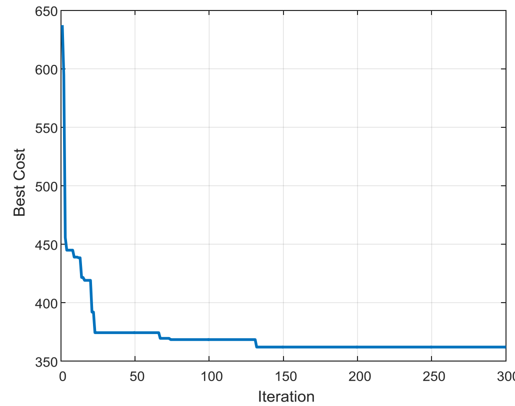

Fig. 6.Gradual convergence of ACO algorithm to a close-to-optimal solution.

Having demonstrated the self-learning nature of the proposed algorithm, next we evaluate its performance in boosting the spatial spectrum reuse inside the cell, through the resource sharing among concurrent D2D transmissions.

IV. Performance Evaluation

In this section, we explain the results of our simulation determined resource allocation algorithm and compare it with algorithms of position-based resource allocation [12] and location and dependent resource allocation [13]. Based on vehicular speed, density, position and direction based on the position is selected the algorithm of resource allocation is allocate different time and frequency resources. The location based on the resource allocation select the a technique for the reuse of spatial resources to optimize available resources, by separation between C-UEs and VEHICULARs using the same resources. In this scenario, the transmission is performed in downlink and uplink and assist both C-UEs and V2Xs. The simulation model consists of the total number of C-UEs and V2Xsreach to 500 users where the of half number for V2Xs of the total number of users and another half number for C-UEs. Positions and distribution inside the sector in rand movement and V2Xs move in freeway scenario , users locations during simulation updated every 100ms. The simulation parameters are presented in Tables I.

TABLE I. Simulation parameters

Parameter	Value
Cell Radius	1.5 km
Number of eNodeB	1
Carrier frequency	2 GHz
System bandwidth	5 MHz
OFDM symbols per slot	6
Number of RBs	25 RBs
Traffic model for CUEs	VoIP, Video, and FTP
VoIP packet generation interval	20 ms
Video packet generation interval	100 ms
FTP packet generation interval	10 ms
Video delay threshold	150 ms
FTP delay threshold	300 ms
C-UEs speed	between 5 and 150 (km/hr)
V2Xs speed	between 30 and 150 (km/hr)
Maximum UEs transmit power	23 dBm
Total Number of V2Xs/C-UEs	100 -500
Simulation length	5000 TTI
TTI length 1 ms	1 ms
Scheduling/Allocation resource	Per TTI
SINRTH	10 dB

The influence of ACO parameters show the By changing the values of the parameters α and β that will be influence the performance of the proposed scheme. We found that when we increase β (heuristic information influence) against of α, the rate of C-UEs increases and the fairness index of C-UEs decreases as shown in Figure (7) and Figure (8), by changing different values for α and β for C-UEs, the comparison between the curves is more important in the fairness index comparing with that the sum rate. Thus, we benefit that by choose α=3 and β=1 will give best network sum rate/fairness index ratio. Furthermore , and we deduce that when increasing α improves so the network sum rate of V2Xs. Decreasing β does not mean that more C-UE RBs will suffer from interference caused by V2Xs.

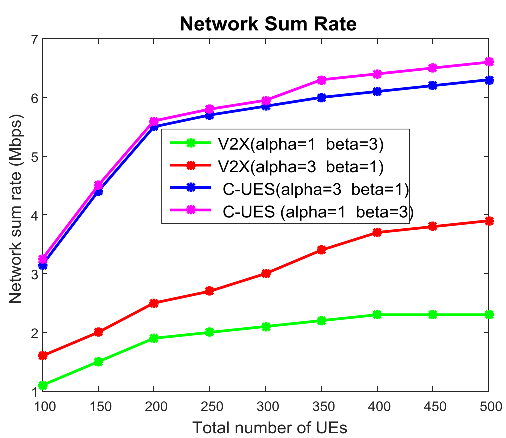

Figure (7) Network Sum Rate

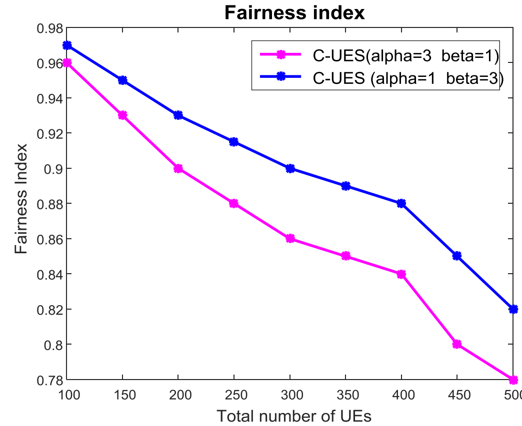

Figure (8) Fairness Index

The average throughput of the user for C-UEs and V2Xs through the cell. Our algorithm reaches the best sum rate as look at the status of the channel in both C-UEs and V2Xs as show in Figure (9) an Figure (10) . It efficiently uses radio resources because it calculates heuristic information based on the number of bits that can be transmitted. High user transmission rate on the RB is useful to help to maximize the probability for the user to customize. As well as in the function of the judge of C-UEs, the user with the lowest probability of outage has the best allocation. As expected, it provides resource allocation based on the worst rate position as the amount assigned a fixed number of RBs to each set of UEs. Also, it does not implement the resource sharing between UEs.

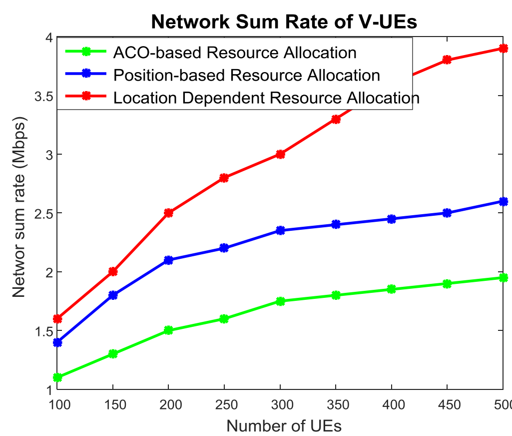

Figure (9) Network Sum Rate of V-UEs

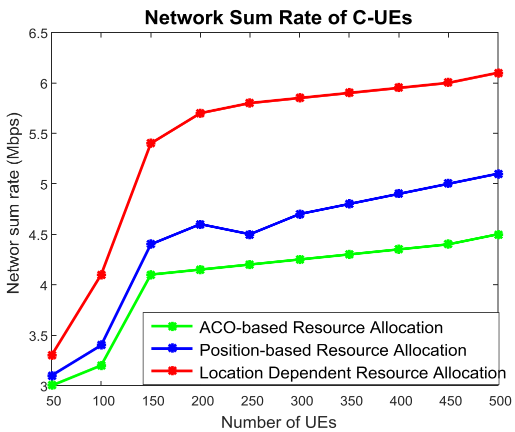

Figure (10) Network Sum of C-UEs

Algorithm of ACO gives a best fairness rates is satisfied as shown in Figure (11) and Figure (12). Due to the status of the channel in a network resource allocation process to make users based on the preceding status of the channel. It is presented allvariation in the status of the channel using global pheromone, which give best equity. The best use of resources in the network is done through sharing using non-orthogonal budget accounts. The proposed algorithm allocates backup budgets in an adaptive manner and implements non-orthogonal budget sharing. Thus, according to Figure (13), the performance of our algorithm in terms of resource utilization ratio is better. Also, according to Figure (14), the proposed algorithm achieves the best rate of popular democracy. On the one hand, BR smart management reduces the rate of popular democracy. On the other hand, a high probability of interruption may increase the PDR rate while the proposed algorithm allocates regional offices to C-UES with the lowest probability of interruption.

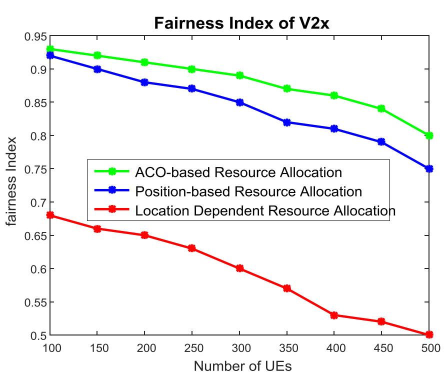

Figure (11) Fairness Index of V2x

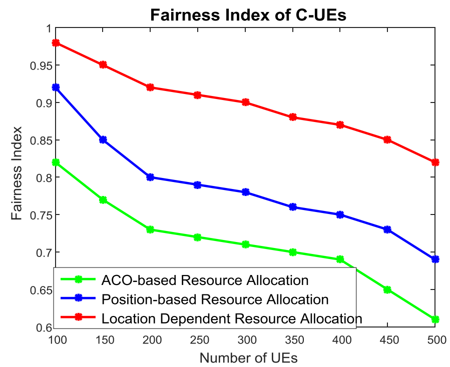

Figure (12) Fairness Index of C-UEs

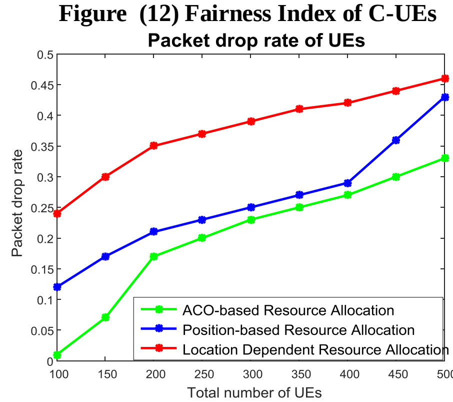

Figure (13) Packet drop rate of C-UEs

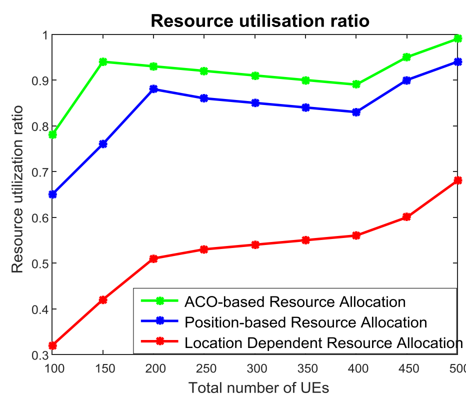

Figure (14) Resource Utilization ratio

V. CONCLUSION

In this paper, We have provided an ACO-based approach for optimize solution to solve the issue of D2D communications resource allocation in LTE-A networks Via network representation as the weighted fee is fully linked. Using these weights, We were able to take into account nuances in interference levels Between the various competing demands D2D requests, and make resource allocation based on decisions. Based on that maximize network rate this is a great advantage to maximize the sum rate to resource allocation techniques. Other interest requirements for QOS we must be take it in consider ation. A Balance between requirements of performance and QoS when we take the consideration of resource allocation in wireless networks is a challenge. In our paper, allocation of resources to balance between C-UEs and V2Xs was taken to maximize the sum rate. An ACO-based system model under the constraint of satisfying the QoS requirements of both V2Xs and C-UEs. We Use mathematical constraints, the resource allocation process has been taken to optimization problem. We take in our interest the requirements for C-UEs and V2Xs to share the same resources. We prefer ACO algorithm to optimize and resolve this problem. The ACO algorithm is compared with two resource allocation algorithms. Simulation results show our algorithm is preferred performance gain. It proceeds better sum rates for cellular and v2x as fairness performance, and get better packet drop rate compared other researcher. Above that, by analysis our algorithm with other resource allocation algorithms, we found that our runtime complexity is much lower and thus optimized due primarily to the pheromone behavior . In fact, the use of pheromone search space greatly reduces the optimal solution taking into account the optimal allocations made so the optimal solution is much lower and satisfying the optimal objectives in throughput, PDR and fairness . It has been demonstrated that the ACO approach is rapidly converging with similar spectrum reuse ratios for the optimal resource distributor that would be impractical for real-time application because of its arithmetic complexity.

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