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Optimization-assisted Resource Exchange Framework for Device-to-device Communication in LTE-advanced System

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Abstract: The proposed system focuses more on maintaining D2D links as long as possible which requires an optimum resource allocation initially. Considering this as the optimization issue, this work finds a solution to solve this by proposing a method based on a hybrid optimization concept with game theory. The hybrid concept includes the hybridization of ant colony optimization and Beluga whale optimization (BWO) with a game theory known as ant Beluga with game theory based optimization (AB-GTO) for resource exchange. This enables frequent updates of interference level indicators of each link and maintains consistent links between devices. The proposed solution will be under the consideration of minimization of interference and maximum sum rate as well. The adopted AB-GTO-based REFD2DC in the LTE-A system employing AB-GTO has a high sum rate value over ACO-Game, T-REX RAN, T-REX DRAN, and T-REX CYC.

Keywords: D2D communication, LTE-Advanced, Resource allocation, Interference, AB-GTO algorithm.

Nomenclature

Abbreviation	Description
ACO	Ant Colony Optimization
AB-GTO	Ant Beluga with Game theory based optimization
BWO	Beluga Whale Optimization
BSs	Base Stations
CQI	Channel Quality Indicator
CUEs	Cell User Equipment
D2D	Device To Device
DRAPC	D2D Resource Allocation And Power Control
DUEs	D2D User
IFO	Integer Carrier Frequency Offset
IoT	Internet of Things
LTE-A	Long-Term Evolution Advanced
MS	Mode Switching
PSSS	Principal Side Link Synchronization Sequence
RBGs	Resource Block Groups
SSI	Side Link Synchronization Identity
SID	Sidelink Identity
3GPP	Third Generation Partnership Project
T-REX	Trader Assisted Resource Exchange
T-REX RAN	Randomized Preference
T-REX CYC	Cycle Complete Preference
T-DRAN	D2D Preferred Randomized Preference
UEs	User Equipments
WPAN	Wireless Personal Area Network
WLAN	Wireless Local Area Network

1. Introduction

One of the major issues with next-generation cellular networks is how to increase coverage and resource use efficiency. D2D communication might increase coverage and resource usage by enabling close-by devices to interact directly with one another [1, 2, 3]. However, resource allocation is a significant problem in D2D communication. It is found that a suitable resource exchange may greatly enhance the transmission efficiency of D2D communications. BSs have historically served as the intermediary infrastructure for multi-hop transmission between two cellular handsets. When both of these devices are close to one another, such a transmission situation is wasteful in terms of resource use and transmission latency [4, 5, 6]. Proximity-based services, or ProSe, are the D2D communications for LTE-A, and the 3GPP has just began standardizing ProSe radio access networks [7, 8].

Using current WLAN or WPAN technologies in an unlicensed band or an LTE-A transmission technique in a licensed frequency, LTE-A enables two adjacent devices to connect with each other directly [9, 10, 11]. This method adds an additional dimension for reusing resources in the basement system, enhances the quality of transmission from proximity, and minimizes transmission latency by using a one-hop direct link rather than a 2-hop link [12, 13, 14]. One of the main difficulties in D2D communication in a cellular system is resource allocation. Licensed or unlicensed spectrum can be used for D2D communications [15, 16, 17].

The BSs should control the allocation of resources of D2D communications when they are using a licensed spectrum in order to: 1) prevent unwanted interference to current cellular users; 2) improve the efficiency of resource use based on (maybe frequency and spatial diverse) channel scenarios; and 3) reuse resources when feasible. The downlink transmission node is used with different complexities and different bandwidths [18, 19, 20]. The BSs should also be able to react promptly to D2D device requests and sudden changes in inter- or intra-cell interference [21, 22, 23]. Therefore, it is essential to create a resource allocation mechanism that is both simple and effective.

Contributions to the proposed work are:

- Develop a new D2D resource allocation paradigm, where, optimal pair selection and resource allocation are done using AB-GTO optimization.
- Performs optimal pair selection and resource allocation on considering minimization of interference and maximum sum rate.

Section 2 describes extant REFD2DC in LTE-A works. Section 3 describes the system model on REFD2DC in LTE-A. Section 4 describes twofold objectives with AB-GTO-based optimization. Finally, sections 5 and 6 explains the results and conclusions.

2. Literature review

2.1 Related works

Zhang *et al.* in 2017 [24] suggested a direct D2D discovering strategy relying on the randomized back-off procedure. D2D UEs randomly selected a back-off period and transmit a beacon. The performance of the suggested system may be greatly improved regarding discovery rate and the discovery latency when compared to existing methods. Based on the investigation, many beneficial guidelines for the design were suggested. Finally, the numerical outcomes shed important light on the performance constraints incorporated into the suggested D2D discovery strategy.

A new D2D resource-allocation paradigm for an LTE-A system was introduced in 2016 by Chih *etal.*[25]. It was demonstrated theoretically that any algorithm, centralized or distributed, converges in the suggested framework when every executed trade was advantageous.

In 2019, You *et al.* [26] suggested a sequential estimation of the IFO and SID in the LTE D2D system. The suggested detection approach made use of the conjugate property of two PSSS to identify the IFO without having knowledge of the SID information in advance. This architecture enabled consecutive analysis of SID and IFO using joint detection. In comparison to existing detection techniques, simulation results have shown that the suggested sequential detection strategy performed well and greatly lowered computing costs.

For D2D communications in the LTE system, Jung *et al*. [27] in 2019 developed an effective frequency resolution and SSI algorithm. The suggested technique was based on the grouping of the PSSS subcarriers to carry out low-cost joint detection. The difference in phase among the PSSS subcarriers was divided into a variety of subsets, each with a specified size. The link between detecting probability and architectural parameters was presented through numerical analysis. Simulations demonstrated that the new technique performed similarly to the previous detection method while having a much lower computing complexity.

A novel sharing paradigm, known as the pure D2D model, was proposed by Lai *et al.* [28] in 2020 to enable DUEs to share resources without engaging CUEs for flexibility. The IoT applications, where the vast majority of devices were often DUEs, benefit from the use of this new approach. The research provided a DRAPC framework and defined an optimization problem to maximize connections supported in the network. DRAPC provided a preliminary categorization of UEs for distributing resources using vertex coloring. Then, in order to improve signal quality and resource sharing, every group was carefully reorganized by switching out participants and including new ones. The results of the simulations demonstrated that DRAPC not only enhanced network speed but also ensured link fairness.

For M2M communications in the LTE/LTE-A network, Upendra *et al.* [29] in 2022 proposed a scalable priority-oriented resource distribution strategy. The existing weaknesses of the optimization process were also highlighted. The suggested resource allocation plan found a compromise between application priority support and resource usage. As per the results, the suggested scheduling algorithm performed better than the usual algorithms in terms of varied metrics.

A detailed concept for a data-plane design for communication between D2D was made in 2018 by Giovanni *et al.* [30]. It specified how communications should take place between the SL and the RP and suggested a solution to the problems with mode transitioning among the SL and RP. We specifically contend that D2D connections must be maintained across cell boundaries in a multicell context and that this can only be done by using two distinct methods of communication on RP. The suggestion was scalable since it doesn't need signaling and was assured not to cause losses. This model was assessed using thorough system-level simulations, paying particular attention to how it interacts with transport-layer protocols.

In 2020, Siba *et al.* [31] introduced a new device discovery method that found nearby UEs without significantly degrading performance. The initial step was to group the cellular UEs into clusters according to their interactions with others and shared interests. After that, each cluster runs a device detection process that consisted of two steps. UEs used the traditional beacon-based discovery strategy to find their neighbors in the first step. By starting the LTE randomized access method, successful UEs report to the BS in the second step. By doing this, the communication overhead was not only lowered, but it facilitated several device discoveries to take place simultaneously at any one moment.

2.2 Problem definition

D2D communication via the cellular network plays a significant supporting role in the rapid rise of context aware applications [24]. D2D communication, however, cannot be achieved without an effective D2D discovery method that uses UEs in the area to look for proximity-based services. Despite its significance, D2D discovery has received relatively little attention and investigation. The internet-assisted D2D discovery needs the D2D UE to be constantly linked to the BS, which results in ineffective use of network resources, high battery usage, and stability challenges. Furthermore, the D2D UEs are frequent power limited, thus the energy-intensive D2D discovery technique is inappropriate for this issue. To lessen energy usage and boost network performance, several studies concentrate on adjusting the probing frequency [29, 30]. The collision reduction during direct D2D discovery is still another crucial component. Currently, discovery techniques based on the greedy selection are frequently presented. Greedy selection necessitates users to browse every resource before choosing the most promising one, which might mitigate some interference to some extent. However, when UEs are positioned near each other, collisions cannot be effectively avoided.

D2D connections may also be employed in big mobile systems, such as trains and sensorized vehicles. In these systems, several UEs may start the handover process almost simultaneously, necessitating an increase of pre-emptive MS activities at the source node. Because signaling messages still need to be scheduled and so compete for resources with other traffic, any MS solution that relies on message exchange would incur a significant cost and could result in cell-wise performance degradations.

3. System mdel on REFD2DC in LTE-A

The adopted model offers essential operations for an LTE-A system for supporting the allocation of resources for communications among D2D [25]. However, additional studies are necessary about the configuration of the service provider (SP) and regulation of D2D communications by the aid of these operations. Assume a mobile system with single BS S and a group of M D2D pair. These D2D pair is inside the service coverage of BS. The coverage is separated into N D2D service area, while the group of D2D pairs in service area n is $B_n = \{b_1^n, b_2^n, \ldots.\}$. There is a group of RBGs $D = \{1,2,\ldots..l\}$ pre-configured in the network. These RBGs are used again in each service region. Every D2D pair necessitates an RBG to carry out D2D transmission, and every D2D pair in the similar service region employs diverse RBGs. Assume $b_i^n \in D$ be the RBG allotted to D2D pair b_i^n in area$n$. Subsequently, the RBG allotment in n is implied as $d_n = \left(d_1^n, d_2^n, \ldots. d_{|B_n|}^n\right)$. Consequently, a fraction of RBGs

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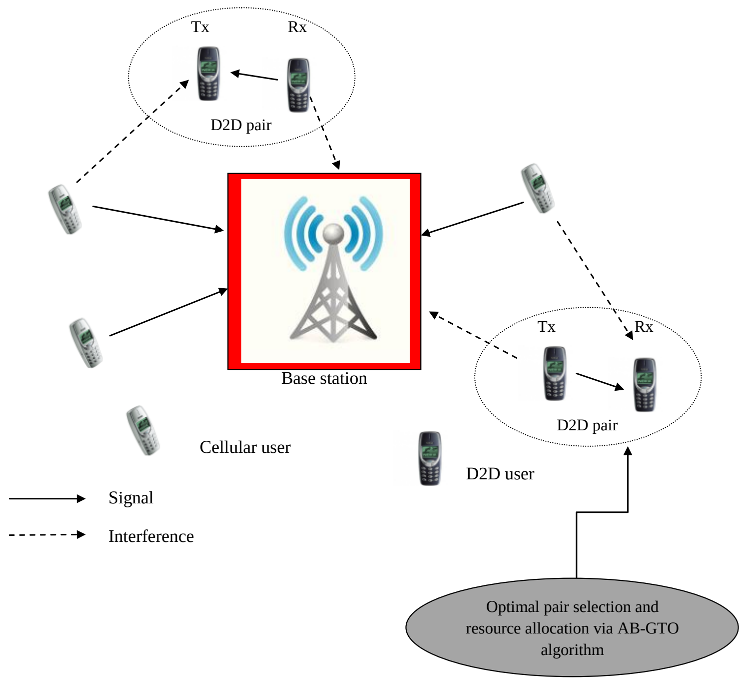


Figure. 1 Architecture of proposedREFD2DC in LTE-A system

$D_n(d_n) = \{j|j \in d_n\} \subset D$is allotted to D2D pairs in n, and other RBGs $D_n^{-1}(d_n) = D\backslash D_n$are hold by BS in n. At last, the overall RBG allotment in every service regions is implied as $d = \{d_n\}$. The intervention practiced by a D2D pair in this approach arrives from other D2D pair, which uses the similar RBG in other service regions. Particularly, assume the intervention practiced by D2D pair b_i^n be I_i^n that is modeled in Eq. (1) [25].

$$I_i^n(d_n, d_{-n}) = \sum_{i' \in B_{n'}, n' \neq n} 1\left(d_{i'}^{n'} = d_i^n\right) p g_{i',i}^{n',n} \quad (1)$$

In Eq. (1), d_{-n}refers to RBG allotment in every service regions, apart from region n; p refers to transmission power of D2D; and $g_{i\prime,i}^{n\prime,n}$ refers to channel gain from jD2D pair in service regionn' to pair i in n. As D2D pairs in the similar region employ diverse RBGs, there is no intra-area intervention, and it enclose $g_{i',i}^{n',n} = 0 \forall i, i' \in B_n$ [25].

Fig. 1 illustrates the recommended AB-GTO oriented model for REFD2DC in LTE-A system.

4. Two fold Objectives with AB-GTO-based Optimization

This work concerns solving the resource exchange problem using game theory.

4.1 Game theory

To examine the problem of revealing the truth, we build a Nash game theory using the suggested framework. There are three elements in a Nash game: participants, actions, and utility functions. We refer to each D2D pair as a player. The experienced SINR is used to define its utility, which is given in Eq. (2). $SINR$ stands for the Signal-to-Interference-plus-Noise Ratio, andΔq refers to the reference signal power of RBGn.

$$CQI_{dB}(n) = \Delta q \left\lfloor \frac{SINR_{dB}(n)}{\Delta q + 0.5} \right\rfloor \quad (2)$$

4.2 T-REX mechanism

In the suggested D2D resource allocation system, the resource exchange issue is addressed via the T-REX mechanism. A centralized resource exchange system called T-REX runs on the eNode B According to the gathered CQIs, it defines the resource exchange sequences for each D2D pair inside the D2D service region. The T-REX method begins by gathering the CQIs from each D2D pair within a service region. Following that, the preference for every D2D pair on RBGs is built in accordance with the provided CQIs. The T-REX technique then creates an exchange graph using D2D pairings' preferences. By looking for cycles in the trade graph, the mechanism in turn determines the exchange sequence. All concerned D2D pairings and traders are then requested to carry out resource exchanges in accordance with the derived exchange sequence.

4.3 Preference for RBG

In diverse RBGs, a D2D pair encounters varying degrees of interference. The D2D pair has more utility if it owns the RBG, and thus the interference will be less and it will be much preferable. The D2D pair b_i^n preference is implied by a relation $\overset{n}{\succ i}$, RBG $j \overset{n}{\succ i} k$ is defined with RBG $j, k \in D$, if and only if b_i^n prefer RBG j over RBG k. The preference $\overset{n}{\succ i}$ of a D2D pair b_i^n is given in Eq. (3).

$$j \overset{n}{\succ i} k \Leftrightarrow I_i^n(d_n | d_i^n = j, d_{-n}) < I_i^n(d_n | d_i^n = k, d_{-n}) \quad (3)$$

Finally, we denote the preference profile of all D2D pairs in B_n as $\succ^n = \left(\overset{n}{\succ 1}, \overset{n}{\succ 2}, \ldots . \overset{n}{\succ |B_n|} \right)$.

Here, the trader approach is proposed. For every service region n, there is a group of traders $T_i^n \in T_n, i = 1 \sim |D_n^{-1}(d_n)|$. The eNode B allocates every unassigned RBG $j \in |D_n^{-1}(d_n)|$ internally to a trader. The preference of trader $\overset{Tr,n}{\succ i}$ for RBGs is specified by a trader preference operation $f_i^n(.)$. It must be noticed that these traders were not the authentic players in the resource-exchanging game as their preferences were controlled directly by eNode D. The T-REX mechanism offers traders for eNode D for regulating the resource-exchanging game.

5. Two Fold Objectives with AB-GTO-based Optimization

The objective taken for AB-GTO-based optimization is shown in Eq. (4). This work focuses on increasing the sum rate $(\Re)$ and reducing the interference (I). In Eq. (4), ω_1 and ω_2 are computed as in Eq. (5).

$$Fit = Min[w_1 * (I) + w_2 * (1 - \Re)] \quad (4)$$

$$w_i = \frac{constraint\,s(i)}{sum(constraint\,s)} \quad (5)$$

5.1 Interference

For an initial allocation of RBG d^0, the aim is to attain the optimal allocation of RBG d^* with the lower interference of the system via exchanging processes. The objective for interference is shown in Eq. (6).

$$\text{Interference} = \min \Sigma\, {}^n{}_i(d) \quad (6)$$

It should be pointed out that the goal may be extended to include additional performance indicators like throughput or latency. As opposed to the other metrics, which may incorporate traffic patterns and considerably raise the level of complexity of the model, it is decided to utilize interference as the aim in this paper since it is more essential and can be connected to CQI information specified in LTE. When different traffic patterns are present, reducing interference typically results in faster throughput and lower latency. We decide to utilize interference as the primary goal of the mechanism because it is such a representative statistic.

In this system, two D2D pairs are able to perform an exchange transaction by swapping their own RBGs. A D2D pair may also trade its RBG with the BS for an RBG that is still not allotted to other D2D pairs. A new allocation d' is generated following the execution of an exchange operation.

An exchange sequence describes a set of exchanges starting with an initial allocation d_0^n within a service region. A virtually randomly allotted RBG may be allocated to a newly arrived D2D pair during the first allocation. Take note that only devices located within the same service region are eligible for swaps. For ease, S_j^n is denoted as the "holder" of RBG $j \in D_n^{-1}(d_n^0)$ at BS. Moreover, an exchanging pair (x, y), in which $x, y \in B_n \cup \{S_j^n | j \in D_n^{-1}(d_n^0)\}$, refers to an exchange among x and y. Subsequently, the exchange sequence s_n will be defined for the service region n as shown in Eq. (7).

$$s_n = [(x_1, y_1), (x_2, y_2), \ldots] \quad (7)$$

The novel RBG allotment d_n is entirely portrayed by the primary allotment d_n^0 and the exchanging sequence s_n . This procedure is denoted as $ex(d_n^0, s_n) = d_n$. Therefore, the aim is to discover the exchange sequence s, which lessens the overall interference in the resource exchanging issue.

5.2 Sum rate

The sum rate of the system is modeled as given in Eq. (8), in which, $\tilde{\delta}_{fk}$ is in the last allocation [32].

$$\Re = \sum_{f=1}^{F} R_{fk} = \sum_{f=1}^{F} \sum_{k=1}^{Q} \tilde{\delta}_{fk}\, U_{fk} \quad (8)$$

Here, E is defined as a set of variables that represents the indices of D2D pairs, which allocate similar resources. It is assumed that the whole pairs are separated into Q groups. R_{fk} is modeled as shown in Eq. (9), R_f^k and R_e^k in Eq. (9) are derived in Eq. (10) and Eq. (11). Therefore, if members of kth $(k = 1,2\ldots.Q)$ D2D user set shares resource with f, the channel rate of UEs f and D2D pair $e' \in E_k$ is modeled as in Eq. (10) and (11). In addition, U_{fk} is derived as in Eq. (12), in which, P_β, P_e and $P_{e\prime}$ refers to transmission power of BS and D2D transmitter e, e' in that order, Q_0 refers to density of Gaussian noise, H_β refers to channel response of BS.

$$R_{fk} = R_f^k + \sum_{e\in E_k} R_e^k \quad (9)$$

$$R_f^k = log_2\left(1 + \frac{P_\beta H_{\beta f}^2}{\sum_{e\in E_k} P_e H_{ef}^2 + Q_0}\right) \quad (10)$$

$$R_e^k = log_2\left(1 + \frac{P_e H_{ee}^2}{P_\beta H_{\beta e}^2 + \sum_{e'\in E_k-\{e\}} P_{e'} H_{e'e}^2 + Q_0}\right) \quad (11)$$

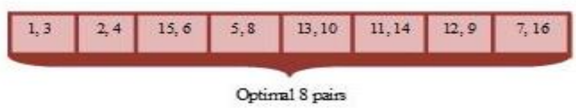
$$U_{fk} = log_2\left(1 + \frac{P_\beta H_{\beta f}^2}{\sum_{e\in E_k} P_e H_{ef}^2 + Q_0}\right) + \sum_{e\in E_k} log_2\left(1 + \frac{P_e H_{ee}^2}{P_\beta H_{\beta e}^2 + \sum_{e'\in E_k-\{e\}} P_{e'} H_{e'e}^2 + Q_0}\right) \quad (12)$$

In this work, the optimal selection of pair and resource allocation is done by means of a new AB-GTO algorithm.

5.3 Solution encoding

This work aims to carry out the optimal selection of pairs and resource allocation for maintaining the D2D links. After choosing the pairs optimally, the resources will be allocated to each of the pair. Here, 16 users are passed as a solution to AB-GTO, from which 8 pairs are determined optimally. Subsequently, resources will be allocated to each optimal pair. For example, consider 16 users as shown in Fig. 2 (a). After optimal selection via AB-GTO algorithm, 8 pairs are obtained as shown in Fig. 2 (b).

(a)



(b)

Figure. 2 Solution encoding: (a) representation of 16 users and (b) optimal pairs

5.4 AB-GTO algorithm

Typically, the ACO algorithm [33] was built around the idea of ant behavior, with an emphasis on the way that ants find food. Based on information from pheromones, ants choose the fastest route to the food source. The ACO model optimization looks like this.

1. Initialization: Distribute the ants m at random, and set the pheromone value to a slight positive parameter.
2. Path construction: Each ant decides where to go next by using the transition probability determined by Eq. (13), where T(ij) points out the pheromone value related to the component c_{ij} and $\phi(.)$ points to a weighted function that gives each possible solution component $c_{ij} \in N(u^p)$ with a heuristic value at each construction stage. Heuristic information is the term used to describe the values provided by the weighting function. Additionally, ϑ and α are positive factors whose values control how pheromone data and heuristic data relate to one another [34].

$$p\left(c_{ij}|u^p\right) = \frac{T_{ij}^{\vartheta}.\phi\left(c_{ij}\right)^{\alpha}}{\sum_{c_{il}\in N(u^p)} T_{ij}^{\vartheta}.\phi\left(c_{ij}\right)^{\alpha}}, \forall c_{ij} \in N(u^p) \quad (13)$$

3. If all of the ants have completed the route that passes through every location, proceed to step 4; otherwise, proceed to step 2.
4. Update on pheromones: The purpose of pheromone updates is to raise the pheromone values connected to successful or promising solutions and lower those connected to unsuccessful ones. This is often accomplished by raising the pheromone levels connected to the selected excellent solution u_{ch} by a specific value ΔT and by lowering all pheromone values via pheromone evaporation.

$$T_{ij} = \begin{cases}(1-\rho)T_{ij} + \rho\Delta T, if T_{ij} \in u_{ch} \\ (1-\rho)T_{ij}, else\end{cases} \quad (14)$$

In Eq. (14), $\rho \in 0,1$ points out evaporating rate. To prevent an algorithmic convergence that is too quick, pheromone evaporation is required. It employs a helpful type of forgetfulness that favors the exploring of new places in searching space.

Conventionally, pheromone update takes place as shown in Eq. (14). As per AB-GTO, T(ij) in Eq. (14) is determined using BWO exploitation update as shown in Eq. (15). The BWO update used for determining T(ij) is shown in Eq. (22).

$$X_i^{\tau+1} = r_3 X_{best}^{\tau} - r_4 X_i^{\tau} + C_1 \times LF \times (X_r^{\tau} - X_i^{\tau}) \quad (15)$$

$$X_i^{\tau+1} = r_3 X_{best}^{\tau} - r_4 X_i^{\tau} + C_1 \times LF \times X_r^{\tau} - C_1 \times LF \times X_i^{\tau} \quad (16)$$

$$X_i^{\tau+1} = r_3 X_{best}^{\tau} + C_1 \times LF \times X_r^{\tau} + X_i^{\tau}(-r_4 - C_1 \times LF) \quad (17)$$

$$X_i^{\tau}(-r_4 - C_1 \times LF) = X_i^{\tau+1} - r_3 X_{best}^{\tau} - C_1 \times LF \times X_r^{\tau} \quad (18)$$

$$X_i^{\tau} = \frac{X_i^{\tau+1} - r_3 X_{best}^{\tau} - C_1 \times LF \times X_r^{\tau}}{(-r_4 - C_1 \times LF)} \quad (19)$$

$$X_i^{\tau} = \frac{X_i^{\tau+1}}{(-r_4 - C_1 \times LF)} - \frac{-r_3 X_{best}^{\tau}}{(-r_4 - C_1 \times LF)} - \frac{C_1 \times LF \times X_r^{\tau}}{(-r_4 - C_1 \times LF)} \quad (20)$$

On combining the conditions in Eq. (14), we get Eq. (21).

$$\begin{array}{l} T_{ij} = (1-\rho)T_{ij} + \rho \Delta T \\ +T_{ij} = (1-\rho)T_{ij} \\ \hline 2T_{ij} = 2(1-\rho)T_{ij} + \rho \Delta T \end{array} \quad (21)$$

$$T_{ij} = \frac{2(1-\rho)T_{ij} + \rho \Delta T}{2} \quad (22)$$

On substituting Eq. (20) in Eq. (22), we get,

$$T_{ij} = \frac{2(1-\rho)\begin{bmatrix} \frac{X_i^{\tau+1}}{(-r_4 - C_1 \times LF)} - \frac{-r_3 X_{best}^{\tau}}{(-r_4 - C_1 \times LF)} \\ - \frac{C_1 \times LF \times X_r^{\tau}}{(-r_4 - C_1 \times LF)} \end{bmatrix} + \rho \Delta T}{2} \quad (23)$$

$$T_{ij} = (1-\rho)\begin{bmatrix} \frac{X_i^{\tau+1}}{(-r_4 - C_1 \times LF)} - \frac{-r_3 X_{best}^{\tau}}{(-r_4 - C_1 \times LF)} \\ - \frac{C_1 \times LF \times X_r^{\tau}}{(-r_4 - C_1 \times LF)} \end{bmatrix} + \rho \Delta T \quad (24)$$

$$T_{ij} = \begin{bmatrix} \frac{-(1-\rho)X_i^{\tau+1}}{(r_4 + C_1 \times LF)} + \frac{(1-\rho) r_3 X_{best}^{\tau}}{(r_4 + C_1 \times LF)} \\ + \frac{(1-\rho) C_1 \times LF \times X_r^{\tau}}{(r_4 + C_1 \times LF)} \end{bmatrix} + \rho \Delta T \quad (25)$$

$$T_{ij} + \frac{-(1-\rho)X_i^{\tau+1}}{(r_4 + C_1 \times LF)} = \begin{bmatrix} \frac{(1-\rho) r_3 X_{best}^{\tau}}{(r_4 + C_1 \times LF)} \\ + \frac{(1-\rho) C_1 \times LF \times X_r^{\tau}}{(r_4 + C_1 \times LF)} \end{bmatrix} + \rho \Delta T \quad (26)$$

Table 1. List of symbols

Variables	Description
$(\Re)$	sum rate
(I)	interference
S_j^n	holder
d_n^0	primary allotment
s	exchange sequence
f	channel rate
H_β	channel response
d_0^n	initial allocation
Q_0	density of Gaussian noise
P_β, P_e and $P_{e'}$	transmission power

$$T_{ij} + \frac{(1-\rho)X_i^{\tau+1}}{(r_4 + C_1 \times LF)} = \begin{bmatrix} \frac{(1-\rho) r_3 X_{best}^{\tau}}{(r_4 + C_1 \times LF)} \\ + \frac{(1-\rho) C_1 \times LF \times X_r^{\tau}}{(r_4 + C_1 \times LF)} \end{bmatrix} + \rho \Delta T \quad (27)$$

$$X_i^{\tau+1}\left[1 + \frac{(1-\rho)}{(r_4 + C_1 \times LF)}\right] = \begin{bmatrix} \frac{(1-\rho) r_3 X_{best}^{\tau}}{(r_4 + C_1 \times LF)} \\ + \frac{(1-\rho) C_1 \times LF \times X_r^{\tau}}{(r_4 + C_1 \times LF)} \end{bmatrix} + \rho \Delta T \quad (28)$$

$$X_i^{\tau+1} = \frac{\begin{bmatrix} \frac{(1-\rho) r_3 X_{best}^{\tau}}{(r_4 + C_1 \times LF)} \\ + \frac{(1-\rho) C_1 \times LF \times X_r^{\tau}}{(r_4 + C_1 \times LF)} \end{bmatrix} + \rho \Delta T}{\left[1 + \frac{(1-\rho)}{(r_4 + C_1 \times LF)}\right]} \quad (29)$$

In Eq. (29), r_3 and r_4 are replaced using the modified quadratic map a shown in Eq. (30).

$$\chi_{n+1} = \left[r - a.e^{\chi_n^2}\right] mod\, 1 \quad (30)$$

5. If the termination measure is fulfilled, the ants will be located randomly or terminated and the obtained optimal solution will be considered.
   The list of symbols are deployed in Table 1.

6. Results and discussion

6.1 Simulation set up

The AB-GTO technique for REFD2DC in the LTE-A system was made in NS3. The evaluation was made for AB-GTO over T-REX RAN [25], T-REX DRAN [24], T-REX CYC [2], and ACO-Game [33]. The examination was done on interference, sum rate, and cumulative basis for varied D2D pair distances of 5 m, 10 m, 15 m, and 20 m. In addition, the service area was varied from 100 m and 200 m and the analysis was made on interference and sum rate.

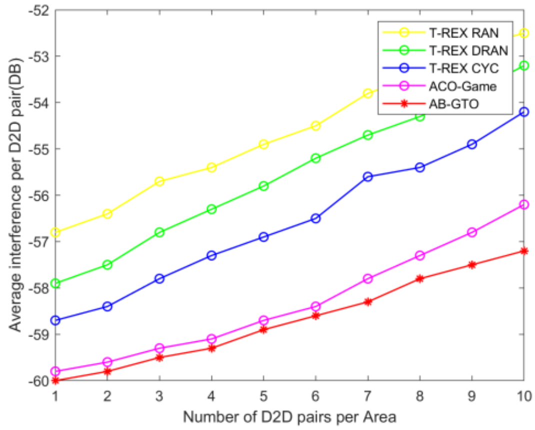


Figure. 3 Interference analysis for service area 100 m for varied D2D pair distances at 5 m

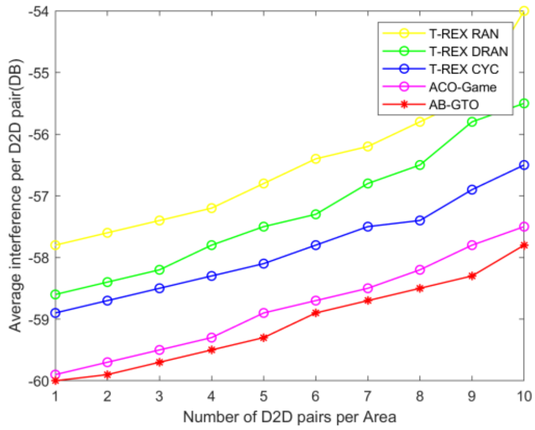


Figure. 4 Interference analysis for service area 100 m for varied D2D pair distances at 10 m

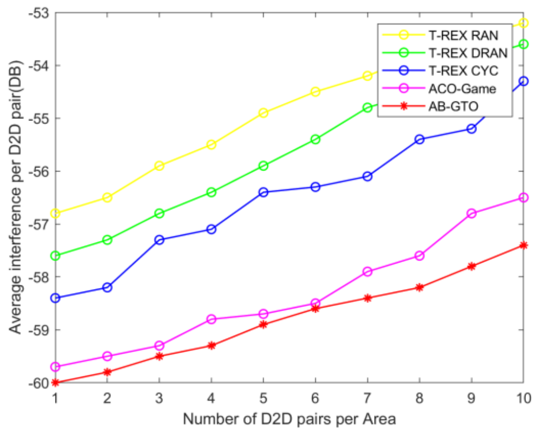


Figure. 5 Interference analysis for service area 100 m for varied D2D pair distances at 15 m

6.2 Interference analysis

The average interference per D2D pair for service area 100 m for varied D2D pair distances of 5 m, 10 m, 15 m, and 20 m is shown in Fig. 3. The average interference values per D2D pair are represented in Db. The analysis is done for average interference vs. number of D2D pairs per area from 1 to 10. The assessment of AB-GTO is performed over T-REX RAN [25], T-REX DRAN [24], T-REX CYC, and ACO-Game. The developedREFD2DC in LTE-A system employing AB-GTO has a low interference value in Fig. 3. Following the developed AB-GTO model, ACO-Game performs well than T-REX CYC, T-REX RAN [25], and T-REX DRAN with low average interference. The T-REX RAN model attains high average interference over other compared systems like AB-GTO, ACO-Game, T-REX DRAN, and T-REX CYC. At the initial count of D2D pairs per area, the average interference is lower; however, as the count of D2D pairs per area increases, the average interference becomes high. Nevertheless, the developed AB-GTO model attains less average interference. Likewise in Fig. 4, the developed REFD2DC in LTE-A system employing AB-GTO has a low average interference value. The T-REX RAN model attains high average interference over other compared systems like ACO-Game, AB-GTO, T-REX DRAN, and T-REX CYC models. Following the developed AB-GTO model, ACO-Gameperforms well than T-REX CYC, T-REX RAN, and T-REX DRAN with low average interference. Similarly, in Fig. 5 and Fig. 6, the developed REFD2DC in LTE-A system employing AB-GTO has attained a low interference value over ACO-Game, T-REX RAN, T-REX DRAN, and T-REX CYC. The interference analysis for D2D pair distance of 5 m for the varied service areas of 100 m and 200 m is shown in Fig. 7, 8. The developed REFD2DC in LTE-A system employing AB-GTO has a low interference value overACO-Game, T-REX RAN, T-REX DRAN, and T-REX CYC. This minimal average interference is due to the new D2D resource allocation paradigm, where, optimal pair selection and resource allocation are done using AB-GTO optimization on considering minimization of interference.

6.3. Cumulative analysis by varying service area

The cumulative analysis by varying service area for 100 m and 200 mis performed usingAB-GTO over ACO-Game, T-REX RAN, T-REX DRAN and T-REX CYC in Fig. 9. The cumulative value should be less, since the objective function is considered as a minimization function with minimal interference and high sum rate. In Fig. 8, the D2D pair distance is set as 5 m, while the service area is varied for 100 m and 200 m. The cumulative values attained by AB-GTO is less, since optimal pair election and resource allocation using AB-GTO optimization is done on

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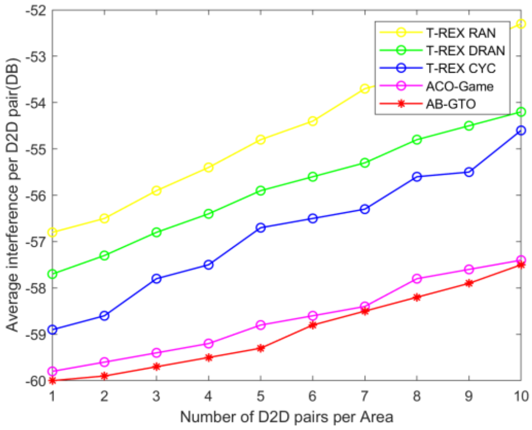

Figure. 6 Interference analysis for service area 100 m for varied D2D pair distances at 20 m

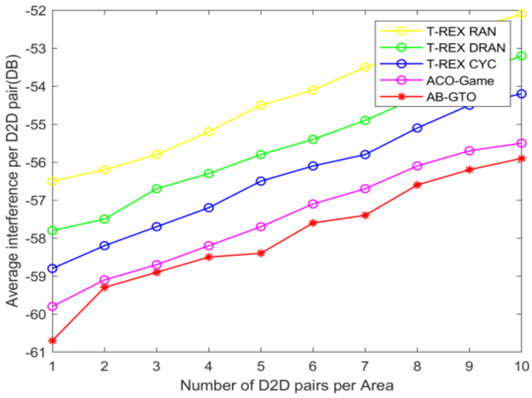

Figure. 7 Interference analysis for D2D pair distance of 5 m for varied service area at 100 m

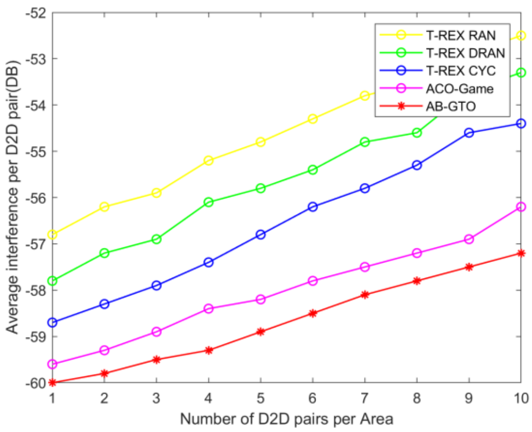

Figure. 8 Interference analysis for D2D pair distance of 5 m for varied service area at 200 m

considering maximization of sum rate and minimization of interference.When the service area is set as 100 m, the new AB-GTO basedREFD2DC in LTE-A system attains less cumulative values of -3.6 while the count of D2D pair per area is 4.Moreover, the cumulative values in Fig. 10 is lower at initial

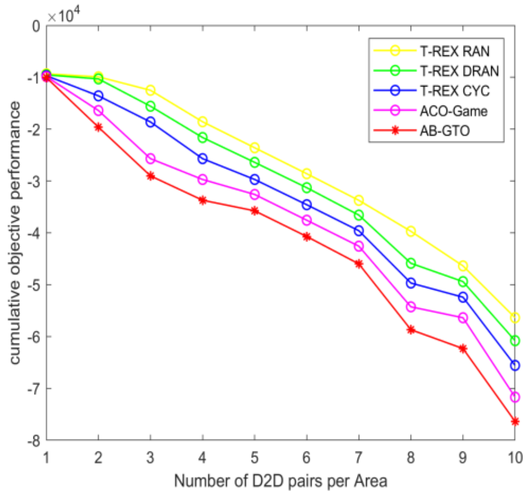

Figure. 9 Cumulative analysis for D2D pair distance of 5 m for varied service area (a) 100 m

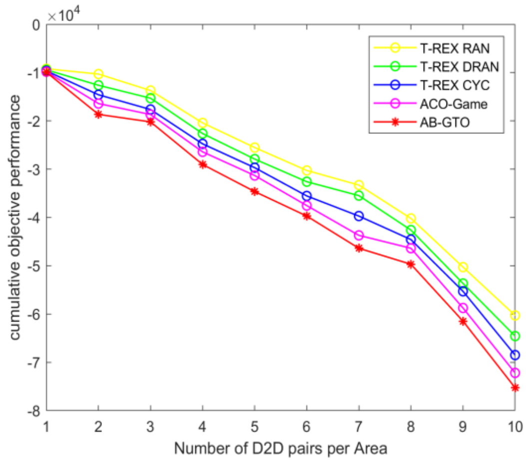

Figure. 10 Cumulative analysis for D2D pair distance of 5 m for varied service area (a) 100 m

count of D2D pairs per area; however, as the count of D2D pairs per area increases, the cumulative values become high. Nevertheless, developed AB-GTO model attains less cumulative values, thus showing high sum rate andless interference.

7. Conclusion

This work introduced a novel D2D resource allocation paradigm for the LTE-A system. The proposed system focused more on maintaining D2D links as long as possible, for which an optimum resource allocation was required. Considering this as the optimization issue, this work found a solution to solve this by proposing a method based on the AB-GTO optimization algorithm. This enabled frequent updates of interference level indicators of each link and maintained consistent links between devices. The proposed solution was under the consideration of minimization of interference and maximum sum rate as well. From analysis, a less interference value of 42 was attained for a D2D pair distance of 20 m and service area of 100 m by AB-GTO, when the value of ρ was 0.8. Moreover, the sum rate value was high around 54 for the proposed AB-GTO when the value of ρ was 0.2. The cumulative value was less for the D2D pair distance of 20 m and service area of 100 m when ρ was 0.8. Mobility issues have to be focused on in the future.

Conflict of interest

The authors declare no conflict of interest

Author contribution

All authors have made substantial contributions to conception and design, revising the manuscript, and the final approval of the version to be published. Also, all authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

[1] J. Yoon, C. Lee, and Y. H. Kim, "Recovery of carrier frequency offset and set information for LTE device-to-device communications", *Journal of Communications and Networks*, Vol. 21, No. 1, pp. 1-11, 2019.

[2] C. Lee, "A collaborative power control and resources allocation for D2D (device-to-device) communication underlaying LTE cellular networks", *Cluster Comput*, Vol. 20, pp. 559–567, 2017.

[3] N. A. Priyadharsini and S. T. Selvi, "Adaptive Spectrum Aggregation Regimen for Downlink NR-gNodeB and Device to Device Systems in 5G", *Wireless Pers Commun*, Vol. 117, pp. 1755–1771, 2021.

[4] G. Nardini, G. Stea, A. Virdis, D. Sabella, and M. Caretti, "Resource allocation for network-controlled device-to-device communications in LTE-Advanced", *Wireless Netw*, Vol. 23, pp. 787–804, 2017.

[5] A. Murkaz, R. Hussain, J. Ahmed, M. Adil, B. Omoniwa, and A. Iqbal, "An intra–inter-cell device-to-device communication scheme to enhance 5G network throughput with delay modeling", *Telecommun Syst*, Vol. 69, pp. 461–475, 2018.

[6] P. K. Mishra, A. Kumar, S. Pandey, and V. P. Singh, "Hybrid Resource Allocation Scheme in Multi-hop Device-to-Device Communication for 5G Networks", *Wireless Pers Commun*, Vol. 103, pp. 2553–2573, 2018.

[7] A. S. Rostami, F. Mohanna, and H. Keshavarz, "Presenting an Optimal Energy-Aware Locating Structure Using the Internet of Things and Device-to-Device Communications on Smartphones", *Wireless Pers Commun*, Vol. 118, pp. 1745–1774, 2021.

[8] M. Subramani and V. B. Kumaravelu, "A Quality-Aware Fuzzy-Logic-Based Vertical Handover Decision Algorithm for Device-to-Device Communication", *Arab J Sci Eng*, Vol. 44, pp. 2413–2425, 2019.

[9] C. Vlachos, V. Friderikos, and M. Dohler, "Optimal Virtualized Inter-Tenant Resource Sharing for Device-to-Device Communications in 5G Networks", *Mobile Netw Appl*, Vol. 22, pp. 1010–1019, 2017.

[10] C. G. Balaji and K. Murugan, "Extending the coverage of evolved Node–B by relaying data using device-to-device offloading in next generation cellular network", *Peer-to-Peer Netw. Appl.*, Vol. 14, pp. 3820–3830, 2021.

[11] S. H. Park, J. S. Kim and M. Y. Chung, "Resource Selection Scheme for the Transmission of Scheduling Assignment in Device-to-Device Communications", *Wireless Pers Commun*, Vol. 97, pp. 4631–4649, 2017.

[12] B. L. Parne, S. Gupta, and N. S. Chaudhari, "PSE-AKA: Performance and security enhanced authentication key agreement protocol for IoT enabled LTE/LTE-A networks", *Peer-to-Peer Netw. Appl.*, Vol. 12, pp. 1156–1177, 2019.

[13] S. A. AlQahtani, "Delay-Aware Resource Allocation for M2M Communications Over LTE-A Networks", *Arab J Sci Eng*, Vol. 44, pp. 3639–3653, 2019.

[14] G. Singh and D. D. Shrimankar, "Dynamic Group Based Efficient Access Authentication and Key Agreement Protocol for MTC in LTE-A Networks", *Wireless Pers Commun*, Vol. 101, pp. 829–856, 2018.

[15] A. N. Babu, J. Vishnu, S. Nandakumar, and T. Velmurugan, "Resource allocation and optimization in D2D communication with PDRAPC framework", *Peer-to-Peer Netw. Appl.*, Vol. 15, pp. 1617–1637, 2022.

[16] Y. Jung, D. Kim, and S. An, "Scalable group-basedmachine-to-machinecommunications in LTE-advanced networks", *Wireless Netw*, Vol. 25, pp. 63–74, 2019.

[17] S. Sharma and B. Singh, "Overlapping Coalition-Based Resource and Power Allocation for Enhanced Performance of Underlaying D2D

Communication", *Arab J Sci Eng*, Vol. 44, pp. 2379–2388, 2019.

[18] H. R. Chayon and H. Ramiah, "Downlink Radio Resource Management Through CoMP and Carrier Aggregation for LTE-Advanced Network", *Wireless Pers Commun*, Vol. 115, pp. 457–481, 2020.

[19] Y. J. Liang and Y. S. Lin, "A non-iterative resource allocation strategy for device-to-device communications in underlaying cellular networks", *Wireless Netw*, Vol. 23, pp. 2485–2497, 2017.

[20] G. Katsinis, E. E. Tsiropoulou, and S. Papavassiliou, "Joint Resource Block and Power Allocation for Interference Management in Device to Device Underlay Cellular Networks", *A Game Theoretic Approach. Mobile Netw Appl*, Vol. 22, pp. 539–551, 2017.

[21] N. B. Halima and H. Boujemâa, "Optimal routing and one hop routing for D2D communications in the presence of mutual interference", *Telecommun Syst*, Vol. 71, pp. 55–64, 2019.

[22] E. Yaacoub, "Cooperative energy efficient D2D clustering in LTE-A with enhanced QoS", *Telecommun Syst*, Vol. 67, pp. 401–414, 2018.

[23] M. V. S. Aditya, H. Pancholi, P. Priyanka, and G. S. Kasbekar, "Beyond the VCG mechanism: truthful reverse auctions for relay selection with high data rates, high base station utility and low interference in D2D networks", *Wireless Netw*, Vol. 26, pp. 3861–3882, 2020.

[24] J. Zhang, L. Deng, X. Li, Y. Zhou, Y. Liang, and Y. Liu, "Novel Device-to-Device Discovery Scheme Based on Random Backoff in LTE-Advanced Networks", *IEEE Transactions on Vehicular Technology*, Vol. 66, No. 12, pp. 11404-11408, 2017.

[25] C. Y. Wang, G. Y. Lin, C .C. Chou, C. W. Yeh, and H. Y. Wei, "Device-to-Device Communication in LTE-Advanced System: A Strategy-Proof Resource Exchange Framework", *IEEE Transactions on Vehicular Technology*, Vol. 65, No. 12, 2016.

[26] Y. H. You, J. H. Park, I. Y. Ahn, and M. Y. Kim, "Low-Complexity Detection of Integer Carrier Frequency Offset and Sidelink Identity for LTE-D2D Communications", *IEEE Wireless Communications Letters*, Vol. 8, No. 5, pp. 1477-1480, 2019.

[27] Y. A. Jung, J. H. Park, and Y. H. You, "Efficient Sidelink Identity Detection and Frequency Ambiguity Resolution for LTE-D2D Communications", *IEEE Access*, Vol. 7, pp. 120500-120507, 2019.

[28] W. K. Lai, Y. C. Wang, H. C. Lin, and J. W. Li, "Efficient Resource Allocation and Power Control for LTE-A D2D Communication With Pure D2D Model", *IEEE Transactions on Vehicular Technology*, Vol. 69, No. 3, pp. 3202-3216, 2020.

[29] U. Singh, A. Dua, and R. Sharma, "Scalable priority-based resource allocation scheme for M2M communication in LTE/LTE-A network", *Computers and Electrical Engineering*, Vol. 103, p. 108321, 2022.

[30] G. Nardini, G. Stea, and A. Virdis, "A scalable data-plane architecture for one-to-one device-to-device communications in LTE-Advanced", *Computer Networks*, Vol. 131, pp. 77-95, 2018.

[31] S. N. Swain and C. S. R. Murthy, " A novel collision aware network assisted device discovery scheme empowering massive D2D communications in 3GPP LTE-A networks", *Computer Networks*, Vol. 169, p. 107071, 2020.

[32] C. Xu, L. Song, Z. Han, Q. Zhao, X. Wang, and B. Jiao, "Interference-aware resource allocation for device-to-device communications as an underlay using sequential second price auction", In: *Proc. of 2012 IEEE International Conference on Communications (ICC)*, 2012.

[33] Z. Chen, S. Zhou, and J. Luo, "A robust ant colony optimization for continuous functions", *Expert Systems with Applications*, Vol. 81, pp. 309-320, 2017.

[34] K. Socha and M. Dorigo, "Ant colony optimization for continuous domains", *European Journal of Operational Research*, Vol. 185, pp. 1155–1173, 2008.