Resource Allocation and Joint Mode Selection for Device-to-Device Communications Using Cuckoo Search Algorithm

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***Abstract*—**In this study, Resource Allocation and Joint Mode Selection for Device-to-Device Communications (D2D) has been modelled using the cuckoo search algorithm (CSA). The implementation is made for equal power control and constraints ensuring that the existing sub-channels are used efficiently and optimally. Simultaneous access to radio resources in a coexistence scenario through D2D technology with optimal mode selection is considered. Initially, the problem formulation for resource allocation is written, then, a cuckoo search optimized solution for optimal resource allocation and mode selection in uplink cellular communications has been proposed and the same has been evaluated using throughput analysis.

Index Terms—Cuckoo search algorithm, device-to-device communications, joint mode selection, resource allocation, orthogonal frequency-division multiple access

I. Introduction

In wireless communication, increased speed and communication quality are important requirements for end users. As the number of users increased, it became increasingly difficult to meet this requirement.One of the researcher suggested to increase the communication spectrum and energy efficiency from device to device (D2D) and to reduce the traffic load [1]. D2D communication is a remarkable method that can be integrated into future wireless networks to improve spectrum utilization, reduce battery consumption, and provide better user experience with increased network efficiency and data speed. D2D communication in cellular network is based on the direct communication of two user devices close to each other by establishing a local connection instead of using a base transceiver station (BTS) to transmit voice and data traffic. In case of transmission problem with BTS, D2D communication can also be used as backup transmission network. On the other hand, the use of D2D communication brings certain problems with it. Interference occurs between cellular users using the same resource and the D2D pair or between D2D pairs using the same resource. It is expected that this interference can be reduced by using two different system models. In the resource allocation and mode selection approach created in the first system model, Orthogonal Frequency Division Multiple Access (OFDMA) system was used. OFDMA is a multiple access technique in which the channel is divided into N orthogonal sub-channels and these sub-channels are shared to users according to secrecy demands. The system model created transmits the data through sub-channels obtained as a result of OFDMA. With the appropriate resource allocation and mode selection approach, it is ensured that existing sub-channels are used efficiently and optimally, and high total user speed levels can be achieved [2]. Cuckoo Search Algorithm (CSA) is preferred for resource allocation and mode selection in order to reduce traffic congestion on network.

Traditionally, in cellular networks, all data transmission takes place through a Base Station (BS), that is, data packets are first sent to the BTS on the uplink and then sent to the recipient on the downlink. However, this traffic creates a significant overhead for the BS as it provides services and reports to many users [3].

When implementing D2D communication, data transmission will occur in direct communication between two devices in close proximity. In this way, BS overhead is reduced by offering more capacity to serve other devices that are not nearby, reducing network congestion and increasing network throughput.

D2D connectivity is expected as part of the import of future 5G and Internet of Things (IoT) applications [3], [4], [5].

In general, interference management is an important issue for D2D communications embedded in cellular systems to ensure uninterrupted communications. However, in order for both devices to work in D2D mode, they must meet the prerequisites. This condition implies not only the proximity of the device, but also a good channel condition, SINR within the specified limit, average bit rate, and low latency.

D2D communication is currently defined by 3GPP (3rd Generation Partnership Project) in LTE-A version 12 and is also recognized as one of the components of future wireless technology (5G) [6].

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The 3GPP group has proposed LTE-A, a standard that is an improved version of LTE, which aims to support a maximum data rate of about 1 Gbps / 500 Mbps (upload / download). To achieve this LTE-A performance, it was decided to integrate more antennas and carrier aggregates in order to provide more channel capacity, inter-device communication (D2D), etc.

Proximity services (ProSe - ProximityServices) will be standardized by 3GPP being directed to the discovery of proximity and direct communication and are part of release 12 of LTE [6].

LTE devices enabled for D2D communication may also become competitive for security in public communication, in the sense that direct communication between devices should work even when cellular networks are unavailable, in the event of disasters or network failures.

In the studies in the literature, resource allocation and mode selection method have been mentioned from different angles [7]-[10]. In the studies examined, resource allocation and mode selection method are used for purposes such as interference reduction, increasing total user speed, system performance and efficiency, and reducing the probability of interruption. In Sun and Shin [8], it has been examined in terms of better system performance and mentions that using the same sub-channel by more than one D2D user pair in D2D communication will provide better system performance. Deng *et al.* [10] aimed to improve the total user speed further by using equal power distribution, and included performance comparison in terms of efficiency and interruption possibility. Su *et al.* [9] stated that the purpose of using resource allocation and mode selection is to reduce the attempt. On the other hand, in the literature studies of resource allocation and mode selection, different algorithms have been preferred. Pang *et al.* [7] proposed resource allocation and mode selection method using evolutionary algorithm optimization. To get rid of the complexity in the evolutionary algorithm, Sun and Shin [8], Su *et al.* [9] applied PSO algorithm as resource allocation and mode selection algorithm. For the resource allocation and mode selection method, the studies on how many D2D pairs the cellular user will use their subchannel are also different. Pang et al. [7] and Sun and Shin [8] considered more than one D2D pair using the same resource. Deng *et al.* [10] and Su *et al.* [9], it is stated that a D2D pair is allowed to use the same resource. Our work utilizes the cuckoo search algorithm for mode selection and resource allocation and it has been shown that algorithm protects D2D services in terms of throughput.

II. Proposed Methodology

The article [11] proposes a solution for integrating D2D functionality into the existing LTE core network architecture. The authors propose the addition of a new equipment, named D2D Server whose role is to provide, maintain, and save the IDs of D2D users. A request for D2D communication for obtaining a given service, which is formulated by a user U_i, is transmitted to the D2D Server via the MME (Mobility Management Entity) equipment of the EPC (Evolved Packet Core) network. Following receipt of the request, D2D Server will request the PCRF (Policy and Charging Rules Function) to verify the right of the U_i user to use the requested service. In the case where he has the right to use it, then D2D Server will provide him with an identifier, otherwise his request will be rejected. This proposal shows different connections of the D2D server with the other devices already implemented in EPC. These different connections allow D2D Server to cooperate with other elements of EPC to perform certain tasks, such as discovering D2D users, managing the mobility of these users as well as establishing D2D calls.

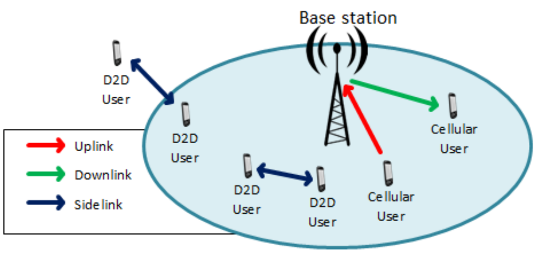

Fig. 1. LTE cellular and LTE-D2D transmissions

The LTE-D2D communications are a mode of LTE communications in which the transmission is carried out using a direct link (Sidelink) between two terminals close to each other, that is, without going through the base station. In Fig. 1 it can be seen how D2D users establish direct communication even out of coverage, while cellular users communicate through the base station. LTE-D2D communications were standardized from LTE Rel.12 for public safety applications [12].

Among its advantages are the reduction of two jumps to one in the communications link and the possibility of operating outside the coverage of the cellular network. Another advantage offered by LTE-D2D communications is the spatial reuse of resources: it is possible for two transmissions within the same cell to be made using the same resources in time and frequency without causing interference between them, as long as both links are far enough away from each other. This space reuse allows to increase the efficiency in the use of radio resources.

Two modes are established for LTE-D2D communications [13]. On the one hand, there is a mode assisted by the cellular network (Mode 1), in which, although the transmission is done directly, it is the base station that indicates to each node the radio resources where it must transmit in time and frequency. In this mode it is possible that cellular and D2D users share the same resources in one channel (Underlying D2D), since the management of resources in the base station is in charge of avoiding interferences between them.

On the other hand, a non-assisted mode (Mode 2) is specified, in which each node independently and randomly chooses the resources to transmit within a given subset of resources. This subset of resources, within the total channel resources, must be reserved exclusively for D2D transmissions (Overlay D2D). Otherwise, D2D users could interfere with cellular transmissions as their selection of resources is not controlled by the base station. The subset of resources reserved for D2D communications is specified by the base station if the terminal is in its coverage, or it uses preconfigured value if it is out of coverage.

Fig. 2 examines basic D2D uplink resource allocation in a cellular system with a set of orthogonal users BS and N. The bandwidth indexed by each user is represented by $i = 1, \ldots, N$.

In Fig. 2, h_i^c shows the mobile user channel i in the BS.

h_i^c denotes the channel from cellular radio user i to a D2D receiver.

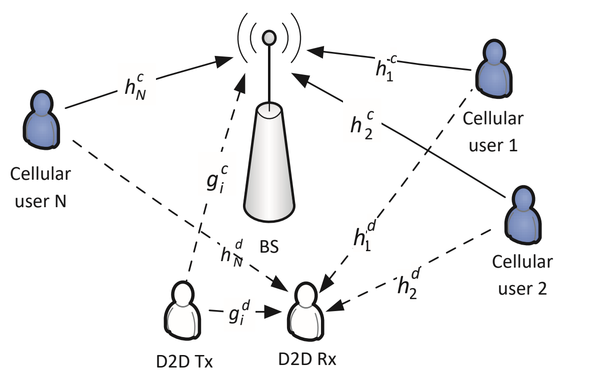

Fig. 2. D2D connection as a sublayer of uplink resource allocation among multiple mobile users [14]

g_i^d denotes a D2D channel transmitter to a receiver in band i.

g_i^c indicates the channel from the D2D transmitter to the transmitter BS in band i.

x_i^c is the transmission signal of cellular user i, and let x_i^d be the transmission signal of user D2D in band i.

The signal received by the mobile user i at the BS is defined as follows:

$$y_i^c = h_i^c x_i^c + g_i^c x_i^d + n_i^c \tag{1}$$

Whereas the signal received by D2D in band i is defined as follows:

$$y_i^d = g_i^d x_i^d + h_i^d x_i^c + n_i^d \tag{2}$$

where n_i^c and n_i^d are zero mean additive Gaussian noise with variance σ_i^c and σ_i^d, respectively.

Suppose cellular users and D2D users use Gaussian code in each frequency band i with transmit power $p_i \triangleq E|x_i^c|^2$ and $q_i \triangleq E\left|x_i^d\right|^2$. Since mobile users and D2D users coexist in the same frequency band, the speed of mobile users i and D2D in frequency band i is given by the expression [14]:

$$\begin{aligned} R_i^c(p_i, q_i) &\triangleq \log\left[1 + \frac{|h_i^c|^2 p_i}{\sigma_i^c + \left|g_i^c\right|^2 q_i}\right] \\ &= \log\left(1 + \frac{\alpha_i p_i}{1 + \theta_i q_i}\right) \end{aligned} \tag{3}$$

$$\begin{aligned} R_i^d(p_i, q_i) &\triangleq \log\left[1 + \frac{\left|g_i^d\right|^2 q_i}{\sigma_i^d + \left|h_i^d\right|^2 p_i}\right] \\ &= \log\left(1 + \frac{\gamma_i q_i}{1 + \beta_i p_i}\right) \end{aligned} \tag{4}$$

where, $\alpha_i \triangleq \frac{|h_i^c|^2}{\sigma_i^c}$, $\beta_i \triangleq \frac{\left|h_i^d\right|^2}{\sigma_i^d}$, $\gamma_i \triangleq \frac{\left|g_i^d\right|^2}{\sigma_i^d}$ and $\theta_i \triangleq \frac{\left|g_i^c\right|^2}{\sigma_i^d}$ are the normalized channel gains.

The allocation of resources between the mobile user and D2D must be designed so that D2D can make the most of it while meeting the needs of the mobile user. To do this, we maximize the performance of a D2D connection by using a range of QoS constraints imposed by mobile users by choosing the right transmit power for both mobile and D2D users. The problem is expressed as [14]:

$$\begin{aligned} &\underset{p,q}{\text{Maximize}} && \sum_{i=1}^{N} R_i^d(p_i, q_i) \\ &\text{subjected to} && R_i^c(p_i, q_i) \geq \rho_i, i = 1, \ldots, N \\ & && 0 \leq p_i \leq P_i, 0 \leq q_i \leq Q_i, i = 1, \ldots, N \\ & && \sum_{i=1}^{N} q_i \leq Q \end{aligned} \tag{5}$$

where ρ_i is the QoS threshold of mobile user i, P_i is the energy budget of mobile users i, Q_i is the power limit of D2D users in frequency band i, and Q is the total energy budget of D2D users in all frequency bands.

Finding the optimal strategy for resource allocation is a tricky task, because it is not hard to see that (5) is a non-convex problem, because $R_i^c(p_i, q_i)$ and $R_i^d(p_i, q_i)$ are not jointly concave in (p_i, q_i). Regardless of these difficulties, this paper provides an optimized solution for (5).

A. Proposed Method for Optimized Resource Allocation

Let the problem in equation (5) is feasible if and only if $\omega_i \triangleq 2^{\rho_i} - 1 \leq \alpha_i P_i \; for \; i = 1, \ldots, N$.

We assume that $\omega_i \leq \alpha_i P_i$, for $i = 1, \ldots, N$ so that the optimal resource allocation occurs.

Let (p^*, q^*) signify the optimal solution to (5).

Define $A_i \triangleq \omega_i \beta_i \theta_i (\alpha_i \gamma_i + \omega_i \beta_i \theta_i)$, $\beta_i \triangleq (\alpha_i + \omega_i \beta_i)(2\omega_i \beta_i \theta_i + \alpha_i \gamma_i)$, $C_i(\lambda) \triangleq (\alpha_i + \omega_i \beta_i)(\alpha_i + \omega_i \beta_i - \frac{1}{\lambda}\alpha_i \gamma_i)$ and $D_i \triangleq \min\left\{Q_i, \frac{1}{\omega_i \theta_i}(\alpha_i P_i - \omega_i)\right\}$ for $i = 1, \ldots, N$. If $\sum_{i=1}^{N} D_i \leq Q \; then \; p_i^* = \frac{\omega_i}{\alpha_i}(1 + \theta_i D_i)$ and $q_i^* = D_i$; if $\sum_{i=1}^{N} D_i > Q \; then \; p_i^* = \frac{\omega_i}{\alpha_i}(1 + \theta_i q_i^*)$ and thus:

$$q_i^* = \left[\frac{\sqrt{B_i^2-4A_iC_i(\lambda)}-B_i}{2A_i}\right]_0^{D_i} \quad (6)$$

where $[\cdot]_0^{D_i}$ denotes the projection onto the interval $[0, D_i]$, and $\lambda > 0$ is selected such that $\sum_{i=1}^{N} q_i^* = 0$.

Substituting p_i^* into $R_i^d(p_i, q_i)$ leads to:

$$R_i^d(p_i, q_i) = \log\left(1 + \frac{\alpha_i\gamma_i q_i}{\alpha_i+\omega_i\beta_i+\omega_i\beta_i\theta_i q_i}\right) \quad (7)$$

Letting $h(q_i) \triangleq \frac{\alpha_i\gamma_i q_i}{(\alpha_i+\omega_i\beta_i+\omega_i\beta_i\theta_i q_i)}$, we get:

$$h''(q_i) = -\frac{2\alpha_i\gamma_i\omega_i\beta_i\theta_i(\alpha_i+\omega_i\beta_i)}{(\alpha_i+\omega_i\beta_i+\omega_i\beta_i\theta_i q_i)^3} \leq 0 \quad (8)$$

Representing that $h(q_i)$ is a concave function. Therefore, equation (5) can be rewrite as the convex problem:

$$\begin{aligned} &\underset{q}{\text{Maximize}} && \sum_{i=1}^{N} \log\left(1 + \frac{\alpha_i\gamma_i q_i}{\alpha_i+\omega_i\beta_i+\omega_i\beta_i\theta_i q_i}\right) \\ &\text{subjected to} && 0 \leq q_i \leq D_i, i = 1, \ldots, N \\ &&& \sum_{i=1}^{N} q_i \leq Q \end{aligned} \quad (9)$$

For each q_i, the objective in (9) is increasing and the optimal solution will be, $q_i^* = D_i$.

Using optimal p_i, optimal q_i and CSA-optimized frequency band the $R_i^d(p_i, q_i)$ is achieved.

B. Proposed Mode Selection System Model

In this study, firstly, a system model with D D2D pairs and N_k cellular users in a single cell is examined. The total number of users is expressed as $k = 1,2, \ldots, K$. By dividing OFDMA channels into sub-channels, the bandwidth is used efficiently and the total end-user speed is reached to the highest level by allocating resources in accordance with the users.

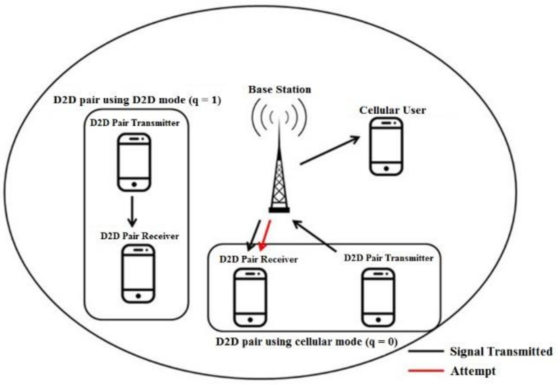

Fig. 3. Resource allocation and mode selection system model

In this case, it is observed that OFDMA method is less affected by the intervention compared to other approaches [15]. Therefore, OFDMA was preferred in this study. The number of sub-channels used in OFDMA is expressed as $n = 1,2, \ldots, N$. In addition, two different modes are used for the other D2D pairs in OFDMA subchannels. The mode used by a D2D pair to communicate directly with D2D pairs without communicating with BTS is $q = 1$. The mode in which the D2D pair reuses the frequency of the cellular user is defined as $q = 0$. The system model of resource allocation and mode selection is shown in Fig. 3. Mode q is n. using the sub-channel k. The speed of the user is expressed in $r_{k,n}^{(q)}$. The user speed of the D2D pair in $q = 1$ mode is defined as $r_{k,n}^{(1)}$.

$$r_{kn}^{(1)} = B\log_2\left(1 + \frac{P_{k,n}^{D2D} G_{k,n}^{D2D}}{P_n + I_{k,n}}\right) \quad (10)$$

Here B denotes the bandwidth. $P_{k,n}^{D2D,max}$ is the maximum power assigned for D2D pairs, equally shared among all D2D pairs, resulting in D2D transmission power, $P_{k,n}^{D2D}$. Using $G_{k,n}^{D2D}$, in the system model, $L_{D2D,k} = 148 + 40\log_{10} d_{D2D,k}$ dB represents the path loss model in D2D pairs [16]. k is the distance between the D2D receiver of the D2D pair and the D2D transmitter is denoted by $d_{D2D,k}$ and taken in km. P_n means thermal noise in the cellular user k. The natural logarithm function is represented by $\log_2(\cdot)$.

Transmission takes place in two time slots as half duplex, therefore uplink and downlink. In the first time slot, the D2D pair transmits the data (upstream) to the BTS, and in the second time slot, the BTS transmits the data (downstream) to the users. Therefore, the user speed depends on the half of the smallest of the user speeds obtained for two time periods [9]. User speed is expressed in $r_{k,n}^{(0)}$ in $q = 1$ mode. The user speed of the D2D pair in $q = 0$ mode is defined by $r_{k,n}^{D2D(0)}$. The speed of the cellular user in $q = 0$ mode is given by $r_{k,n}^{HK(0)}$:

$$r_{k,n}^{D2D(0)} = \left(\frac{1}{2}\right)\min\left[B\log_2\left(1 + \frac{P_{k,n}^{BTS} G_{k,n}^{BTS}}{P_n + I_{k,n}}\right), B\log_2\left(1 + \frac{P_{k,n}^{D2D} G_{k,n}^{BTS}}{P_n + I_{BTS,n}}\right)\right] \quad k \in D2D \quad (11)$$

$$r_{k,n}^{HK(0)} = B\log_2\left(1 + \frac{P_{k,n}^{BTS} G_{k,n}^{BTS}}{P_n + I_{k,n}}\right) \quad k \in HK \quad (12)$$

Here, the BTS is transmit power, $P_{k,n}^{BTS,max}$, is obtained by equally sharing the assigned maximum power for BTS between $P_{k,n}^{BTS}$ sub-channels. In the system model using $G_{k,n}^{BTS}$, $L_{BTS,k} = 128 + 37.6\log_{10} d_{BTS,k}$ dB represents the path loss model that affects cellular users from BTS or from BTS to D2D pair [16]. The distance between BTS and k cellular users is indicated by $d_{BTS,k}$ and taken in km. $I_{BTS,n}$ defines the interference that occurs in BTS. In this study, equal power allocation is taken into account. Maximum power is divided equally among users [10].

For the CSA-based resource allocation and mode selection algorithm used in this study, a random matrix with $m = 1,2, \ldots, M$ size and $2N$ sub-channels is generated. The first half of the $2N$ sub-channel represents users using cellular mode and the second half represents users using D2D mode. It is passed from the matrix x_m^{2N}, whose size is $M \times 2N$, to the matrix used for $x_{k,n}^{(q)}$ resource allocation and mode selection assignment:

$$Q(x_m^n) = \lfloor x_m^n (K+1) \rfloor, \ \ x_m^n \in (0,1) \tag{13}$$

$$Q(x_m^{N+n}) = \lceil x_m^{N+n} (D+1) \rceil + N_k, \ \ x_m^{N+n} \in (0,1) \tag{14}$$

Here, $\lfloor \cdot \rfloor$ the base operator is the largest integer less than itself, and $\lceil \cdot \rceil$ the ceiling operator is greater than itself. They are mathematical functions that round to the smallest integer. With the help of (13) and (14), $Q(x_m^n)$ derives a value between 0 and K, and if $Q(x_m^{N+n})$ is $N_k + 1$, a value between $K + 1$. $Q(x_m^n)$, $Q(x_m^{N+n})$ values (15) are used to obtain a x_k matrix consisting of 1 if k users are assigned to n sub channels and 0 if they are not. The size of the resulting $x_{k,n}^{(q)}$ matrix is $M \times 2N$:

$$x_{k,n}^{(q)} = \begin{cases} 1, \ if \ k = Q(x_m^n) \ and \ q = 0 \\ 1, \ if \ k = Q(x_m^{N+n}) \ and \ q = 1 \\ 0, \quad Otherwise \end{cases} \tag{15}$$

The $r_{k,n}^{(q)}$ matrix obtained after the CSA-based resource allocation and mode selection is completed is used for the fitness function U given by (16).

$$U = \sum_k \sum_n \sum_q x_{k,n}^{(q)} r_{k,n}^{(q)} \tag{16}$$

There are some limitations in CSA-based resource allocation and mode selection process: These limitations include the inability of cellular users to use the $q = 1$ mode, the presence of only one D2D pair in each sub-channel to prevent interference caused by the D2D pair using the same sub-channel as another D2D pair, the cellular user and D2D pairs can choose one mode, the subchannels generated as a result of OFDMA can use at most one cellular user and one D2D pair.

C. Cuckoo Search Algorithm (CSA)

Cuckoos attract birds not only with beautiful songs, but also with an aggressive breeding strategy. Some species, such as Guira and Anis, lay their eggs in public nests. You can also remove eggs from the host bird to increase the chance of eggs hatching. Many species become infected with wild parasitism, laying eggs in the nests of other hosts, which usually belong to other species [17]. There are three main types of parasitism: a) intraspecific droppings, b) cooperative reproduction, and c) nesting by acquisition.

Cuckoo search is a metaheuristic inspired by the behavior of parasitic cuckoos developed by [18]. Consider three rules: 1) each cuckoo lays eggs and lays eggs in randomly selected nests; 2) Nests with quality eggs are selected for the next generation. 3) The number of available nests is fixed, and the owner finds eggs laid by cuckoos with a variable probability in the interval [0, 1]. CSA uses a balanced combination of local random path (local search) and global random search (global search), driven by the p_a parameter.

Local search can be written like this:

$$x_i^{t+1} = x_i^t + \alpha s \oplus H(p_a - \epsilon) \oplus (x_j^t - x_k^t) \tag{17}$$

where t is the current iteration, x_j^t and x_k^t are two different solutions selected at random by a random permutation, α is the scaling factor of s, with s is the size of the step. $\oplus$ is the internal product between two vectors, $H(.)$ is the function of Heaviside and ϵ is a number generated randomly from a uniform distribution. The global search is already carried out using Lévy flights, as shown in the following equation:

$$x_i^{t+1} = x_i^t + \alpha L(s, \lambda) \tag{18}$$

where,

$$L \sim \frac{\lambda \Gamma(\lambda) \sin\left(\frac{\pi \lambda}{2}\right)}{\pi} \frac{1}{s^{1+\lambda}}, \qquad (s \gg s_0 > 0) \tag{19}$$

Γ is the standard gamma function, the distribution of which is valid for distant steps. Generating a pseudo-random step size according to equation (19) is not a trivial task [18]. There are several methods for generating random numbers, and the most efficient is the Mantegna algorithm [19]. In this algorithm, the step size s can be calculated using two Gaussian distributions U and V according to the following equation:

$$s = \frac{U}{|V|^{\frac{1}{\lambda}}} \tag{20}$$

With,

$$U \sim N(0, \sigma^2), \ \ V \sim N(0,1) \tag{21}$$

where $U \sim N(0, \sigma^2)$ means that the samples are generated from a normal Gaussian distribution, with zero mean and variance σ^2, calculated by:

$$\sigma^2 = \left[\frac{\Gamma(1+\lambda)}{\lambda \Gamma\left(\frac{1+\lambda}{2}\right)} \cdot \frac{\sin\left(\frac{\pi\lambda}{2}\right)}{2^{\frac{\lambda-1}{2}}} \right]^{\frac{1}{\lambda}} \tag{22}$$

On the basis of the three rules previously defined, the basic stages of the CSA can be represented in the pseudo code of algorithm. Initially, the nest population is generated randomly (line 1). In line 3, a cuckoo is chosen randomly through the flight of Lévy, according to Equation (18). In line 4, the objective function of the previous nest was evaluated. In the next line, a nest *j* is randomly chosen. Then, in line 6, it is checked whether the value f_i is better than f_j (value calculated in objective function f for nest *j*), if positive, nest *j* is replaced by the new nest *i* (line 7). In line 9, a fraction (represented by parameter p_a) of the worst nests is abandoned. In line 10, the solutions are evaluated and the best ones are maintained. Finally, on line 11, the solutions are classified and the best one is selected.

Pseudo-code of the Cuckoo Search Algorithm

1. Create the initial population of n host nests $x_i = (i = 1,2,\dots,n)$
2. As long as the stopping criteria is not easily reached
3. Get a cuckoo randomly using Lévy flight
4. Evaluate the objective function f_i
5 Choose a random nest j
6. if $f_i > f_j$ then
7. Replace j with the new solution
8. end if
9. Abandon p_a, fraction of the worst nests and build new ones
10. Keep the best solutions
11. Rate the solutions and find the best one
12. End while

III. Simulation Results

We are considering a single cellular network with a radius of 500 m, the eNB is in the center of the cell, and the normal CU is evenly distributed within the cell. DU is positioned according to the cluster distribution model, where each D2D S_k emitter is uniformly distributed inside the cell, and the D2D R_k receiver is evenly distributed on a disk centered at the center of the corresponding D2D S_k emitter and radius r. The simulation parameters are summarized in Table I. Cellular Mode Probability (CMP) decreases with the number of DUs for both scenarios as multiple DUs must operate in ad hoc or reuse mode to allow more UDs in the system for K. In addition, CMP increases with increasing distance D2D, r, because D2D communication is less competitive when the distance between D2D pairs is large. In a moderate load scenario, the CMP is very small.

TABLE I: Simulation Parameters

Cell radius	500m
D2d distance	20-100m
Uplink bandwidth	3 MHz
Noise Spectral Density	–174 dBm/Hz
Path loss model for cellular links	128.1+37.6log (d[km])
Path loss model for D2D links	148+40log (d[km])
Shadowing standard deviation	10 dB
SINR threshold	10 dB
Number of CUs	10-20
Number of D2D pairs	1-15
Maximum transmit power of cell users (CU)	18-27 dBm
Maximum transmit power of D2D users (DU)	18-27 dBm
Number of uplink channels	20
Number of downlink channels	20

Fig. 4 and Fig. 5 show the overall system performance of various algorithms in a moderate load scenario where NU = ND = 2, K = 8 and M = 18. Ignoring the cell mode has little performance impact, indicating that the optimal cuckoo search algorithm is efficient for moderate load scenarios. Worst performance in Hungarian fashion.

Let's now look at the approaches to proximity gain, the hop gain, and the reuse gain in light and medium load scenarios. The maximum transmit power of DU and CU is set at 24 dBm.

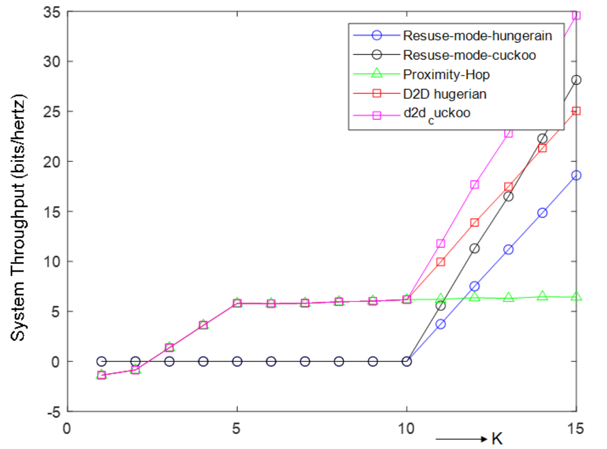

Fig. 4. Total system throughput and throughput gains for different D2D numbers

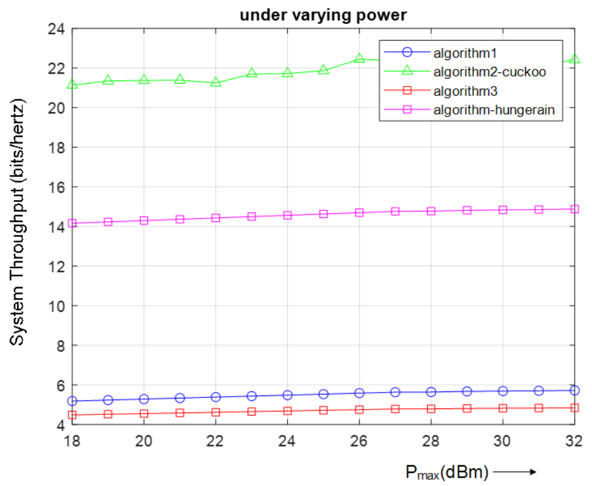

Fig. 5. Total system throughput for various maximum transmission powers

The total system throughput is shown in Figure 6, where the number of downlink and uplink channels is 20, the number of CUs is 15, and the number of D2D pairs is 1 to 15. In this case, the number of empty channels in both the downlink and uplink channel - 5, i.e. NU = ND = 5. From the figure, if the system is equipped with a load indicator (K ≤ 10), almost all D2D pairs allowed by Algorithm 1, Performance Algorithm 1 is close to Algorithm. 2 because channel reuse is unlikely. When the system switches from light to moderate load (K> 10), some D2D pairs need to operate in reuse mode. Therefore, Algorithm 2 is superior to Algorithm 1 because the D2D pair can reuse the CU. In this case, you can benefit from reuse. If the system has a very low load (K 5), all DUs can be resolved by Algorithm 3 as normal CPUs. In this case, the proximity gain is observed by comparing algorithms 3 and 1 (or 2). The performance gap between Algorithms 1 and 3 widens rapidly with increasing network load (K> 5) due to step gain. In addition, for K> 5, although the number of D2D pairs allowed in Algorithm 3 remains 5, the overall throughput is still increased due to the inherent multiuser diversity. The same phenomenon can be observed in Algorithm 1 for K> 10.

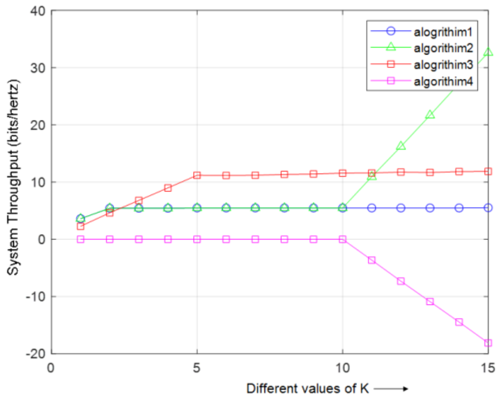

Fig. 6. Total system throughput and throughput gains for various D2D numbers

The reuse gain is obtained by comparing Algorithms 4, 2, and 1, while the proximity gain plus the hop gain is obtained by comparing Algorithms 1 and 3. The D2D gain is the sum of proximity gain, the hop gain, and the reuse gain. In a low load scenario ($K \leq 10$), the D2D gain is dominated by hop gain and proximity gain, since there is enough empty channel and line reuse is not required. Meanwhile, for the medium load scenario (K>10), the increase in D2D gain is mainly due to reuse gain. In this case, the proximity gain and the hop gain increase slightly due to multi-user diversity.

IV. Conclusion

In this research work, we consider concurrent access to radio resources in a coexistence scenario using D2D (device-to-device) technology. In this work, we propose a resource allocation algorithm optimized for D2D communication to improve network performance using cuckoo search optimization technique. The mode selection and resource allocation problem is generated by the base uplink resource of a plurality of mobile users. The number of frequency bands is then optimized using various optimization techniques. The simulation results show that our algorithm protects D2D services in terms of throughput. Ignoring the cell mode has little performance impact, indicating that the optimal cuckoo search algorithm is efficient for moderate load scenarios.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All authors had contributed to this work.

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