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Comparison of Different Resource Allocation Strategy for Device-to-Device Communication

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Abstract –**The introduction of device-to-device communication (D2D) in future cellular networks will be subject to a considerable degradation of the performance of existing traditional applications called human-to-human (H2H). In this paper, we consider simultaneous access to radio resources in coexistence scenario through device-to-device (D2D) technology. First, we formulate the problem of resource sharing, then, we propose a genetically optimized solution for optimal resource sharing in uplink cellular communications. The performance is evaluated using the throughput analysis.**

Keywords –**D2D, Genetic Algorithm, H2H, LTE.**

I. Introduction

In the world of telecommunications, mobile network technologies are divided into what has been called generations [1]. Global Systems for Mobile Communications (GSM), whose main innovation was to increase the capacity of the devices and allow the exchange of data, low speed, and SMS. Later the 2.5G appeared, General Packet Radio Services (GPRS), which makes the exchange of data packages on cellular systems a reality in the second half of the 90s. Then Mobile 3G networks are deployed, based on Wideband Code Division Multiple Access (W-CDMA), Universal Mobile Telecommunications System (UMTS) and later its update called 3.5G High-Speed Packet Access (HSPA)[2,3,4].

The LTE-D2D communications are a mode of LTE communications in which the transmission is carried out using a direct link (Side link) between two terminals close to each other, that is, without going through the base station [5,6]. LTE-D2D communications were standardized from Released 12 for public safety applications [7,8]. it is possible for two transmissions Two modes are established for LTE-D2D communications. 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. 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) [9]. 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 values if it is out of coverage.

The rest of paper is organized as follows- In section 2 the resource sharing scheme is define. In section 3 problem formation is presented. The performance evolution of our proposed method is illustrated in section 4, followed by result in section 5 and conclusion in section 6.

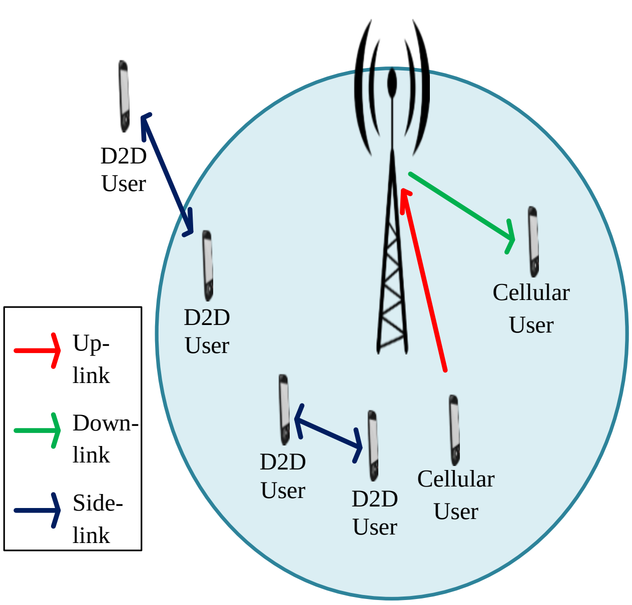

Fig. 1: LTE cellular and LTE-D2D transmissions

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II. SYSTEM MODEL

Fig.1 shows 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 paper shows different connections of the D2D server with the other devices already implemented in EPC.

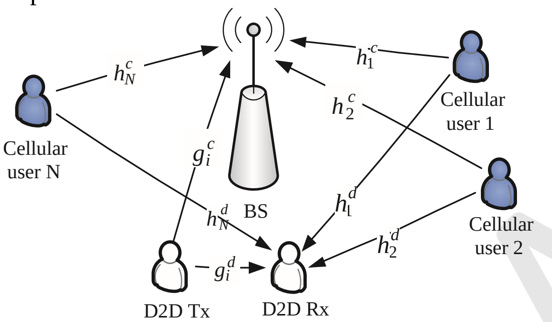

Fig. 2: One D2D link as an underlay shares uplink resources of multiple cellular users [10]

Figure 2 considers underlying D2D communication sharing uplink resources in a cellular system having one base station (BS) and N number of orthogonal users. The frequency band indexed by each user is expressed by $i = 1, \ldots, N$.

The received signal of cellular user i at the BS is given by:

$$y_i^c = h_i^c x_i^c + g_i^c x_i^d + n_i^c \quad (1)$$

Whereas the D2D received signal on frequency band i is given by:

$$y_i^d = g_i^d x_i^d + h_i^d x_i^c + n_i^d \quad (2)$$

Where n_i^c and n_i^d are the additive zero-mean Gaussian noise with variances σ_i^c and σ_i^d, respectively.

Table.1 Description of Parameter

S. No	Name of Parameter	Symbol
1	Channel from cellular user to BS	h_i^c
2	Channel from cellular user to D2D receiver	h_i^d
3	Channel from D2D transmitter to BS	g_i^c
4	Channel from D2D transmitter to its receiver	g_i^d
5	Transmit signal by cellular user	x_i^c
6	Transmit signal by D2D user	x_i^d

Assume that both the cellular users and the D2D user use Gaussian codes on each frequency band i with transmit power $p_i \triangleq E|x_i^c|^2$ and $q_i \triangleq E|x_i^d|^2$. Due to the coexistence of cellular and D2D users on the same frequency band, the throughputs of the cellular user i and the D2D user on the frequency band i are given respectively by [10]:

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

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

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

The resource sharing between the cellular and D2D users must be elegantly designed so that the D2D can achieve the maximum benefit while the cellular users' requirements are always satisfied to accomplish this, we maximize the throughput of the D2D link with a group of QoS constraints imposed by the cellular users, by properly choosing the transmit power of the cellular and D2D users. The problem is expressed as [10]:

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

Where ρ_i is the QoS threshold of cellular user i, P_i is the power budget of cellular user i, Q_i is the power limit of the D2D user on frequency band i, and Q is the total power budget of the D2D user on all frequency bands.

Finding the optimal resource sharing strategy is a respectively. challenging task, as it is not difficult to see that (5) is a non-convex problem since both $R_i^c(p_i, q_i)$ and $R_i^d(p_i, q_i)$ are not jointly concave in (p_i, q_i). Despite this difficulty, this paper provides a genetically optimized solution to (5).

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III. Formation of Problem

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 sharing exists.

Let (p^*, q^*) denote the optimalsolution 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:

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

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

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

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

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:

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

Indicating that $h(q_i)$ is a concave function. Consequently, (5) can be simplified to the following convex problem:

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

The objective in (9) is increasing in each q_i, the optimal solution is simply $q_i^* = D_i$.

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

IV. Proposed Method

Genetic Algorithm (GA)

Genetic algorithms (GA) are optimization algorithms based on techniques derived from genetics and natural evolution. A genetic algorithm is defined by the following characteristics:

Squence / Chromosome / Individual (binary coding): "We call a sequence (chromosome, individual) A of length l (A) a sequence A = {a1, a2, ..., al} with ∀i ∈ [1, l], ai ∈ V = {0,1} ".

A chromosome is therefore a sequence of bits in binary coding, also called binary string. In the case of a non-binary coding, such as the actual coding, the sequence A contains only a real point, we have:

$$A = \{a\} \text{ with } a \in \Re \qquad (10)$$

- Population: A set of chromosomes or points in the search space.
- Gene: A gene will be a part of a solution to the problem, therefore of an individual.
- Environment: The research space.
- Fitness Function: The positive function that we seek to maximize.

The first step is to properly define and code the problem.. Thus, this phase determines the data structure that will be used to encode the genotype of individuals in the population. The coding must therefore be adapted to the problem addressed. Several types of encodings are used in the literature, including coding by a fixed-length binary sequence and actual coding.

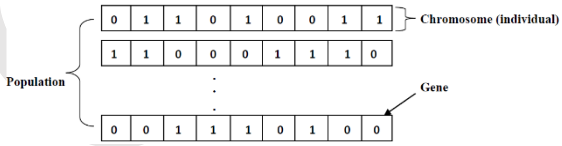

Fig. 3: Binary coding of data for the genetic algorithm

The operation of genetic algorithms is extremely simple, we start from a population of potential solutions (chromosomes) initial, arbitrarily chosen or in any way. We evaluate their relative fitness. Based on these performances we generate a new population of potential solutions using simple evolutionary operators: selection, crossover and mutation. Some individuals reproduce, others disappear and only the best adapted individuals are expected to survive. We start this cycle again until we find a satisfactory solution. Indeed, the genetic inheritance through the generations allows the population to be adapted and thus to answer the criterion of optimization.

V. Result and Discussion

It is assumed that the cellular users are uniformly distributed in a hexagonal cell having a radius of 500m. Figure 4 shows the average D2D throughput with conventional frequency band for 8 users. The SNR range is 0 to 16 dB. It was found that, at low D2D SNR, this approach tends to allocate limited power in conventional frequency band. Figure 5 shows the average D2D throughput with optimized frequency band for 8 users. The SNR range is 0 to 16 dB. It is found that the optimal strategy provides

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the best performance for D2D communication. Figure 6 shows a comparison of throughput responses with optimal strategy and Genetic Algorithm. The D2D link causes less interference to the cellular users as it moves away from the BS. Hence, given the cellular QoS constraints, the D2D link can use more power on cellular frequency band and thus achieve higher throughputs while using the GA. Again, one can see that the resource sharing with multiple cellular users (Optimal strategy) is usually better than that with one cellular user.

Table 2: Simulation parameters

S. No.	Parameter Name	Value
1	Base station (BS)	1
2	No. of frequency band	8
3	No. of cellular user	8
4	No. of D2D receiver	1
5	D2D SNR range	0 to 16

Table 3: D2D SNR and average throughput (bits/S/H)

S. No.	D2D SNR (DB)	Avg. Throughput (Bits/S/H)	
		Optimal Strategy	Genetic Algorithm
1	0	0.976	3.200
2	2	1.083	3.599
3	4	1.245	3.929
4	6	1.442	4.453
5	8	1.642	4.875
6	10	1.859	5.145
7	12	2.092	5.745
8	14	2.339	6.168
9	16	2.598	6.643

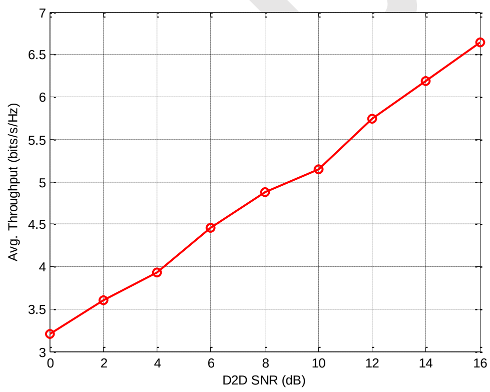

Fig. 4: Throughput response with conventional frequency band

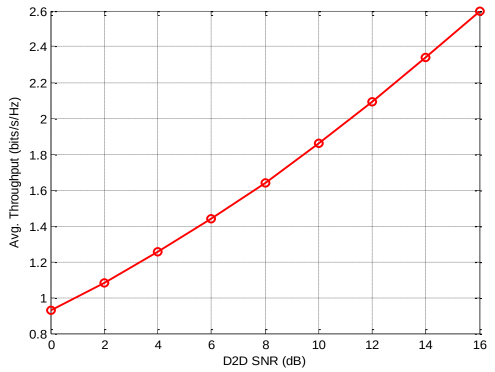

Fig. 5: Throughput response with optimized frequency band

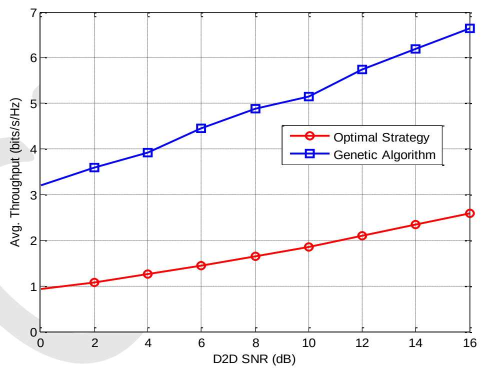

Fig. 6: Comparison of throughput responses with optimal strategy and Genetic Algorithm

VI. CONCLUSION

In this work, we have proposed an optimized resource sharing algorithm for D2D communications to improve network throughput using Genetic Algorithm (GA). The resource sharing problem is modelled by underlay uplink resources of multiple cellular users. Next, the number of frequency band is optimized using the GA. The simulation results show that our algorithm protects D2D services in terms of throughput.

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