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Resource Pooling Coupled with Power Adaptation for the Management of Interferences between Cellular and D2D Communications in 5G

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Abstract: As telecommunication networks are booming, we are witnessing an ever-increasing evolution of network generations. These evolutions are due both to the ever-higher demands of subscribers and services. Thus, the world we live in is moving towards a global interconnection of information systems and equipment, with an ever-increasing demand in terms of throughput, in terms of low latency, and reliability. This is why we have seen the evolution from the First-Generation Network (1G) to the Fifth Generation (5G) nowadays. Being in the era of the fifth generation, there are several objectives that must be achieved, namely: Ultra-high-speed communication, low latency, ultra-reliable communication, and a large number of objects communicating with each other. However, if the communication is to be done while respecting all these constraints, the network access nodes may be overloaded. Thus, D2D technology ensures communication between a large number of objects in the network; it helps relieve the load on network access nodes such as geodes. In this study, we focused on D2D communication reusing the spectral resources allocated to cellular users, which is the case of In-Band Underlay. Although this type of communication is very advantageous, it creates several interferences in traditional cellular communication. This study's objective aimed to reduce these interferences created in cellular communication, in particular and, in a secondary way, in D2D communication through the use of a Resource Pooling algorithm coupled with Power Adaptation.

Keywords: 5G, D2D, gNodeB, Resource Pooling, Power Adaptation

Introduction

Communication networks are in perpetual evolution due to the ever-increasing communication needs of users (Ericsson Mobility Report, 2024). Indeed, telecommunications operators and players are constantly searching for methods and means to meet the needs of network users. This need to satisfy the growing demand from users has led to the evolution of the network in terms of generation, starting from the First Generation (1G), through the Third (3G), up to the Fifth (5G) of today. 5G comes (Bhalla and Bhalla, 2010; Dangi *et al.*, 2021) with the aim of meeting the very high needs that already exist, as well as the needs that will arise in the future.

The advent of 5G paves the way for new use cases, among which Device-to-Device (D2D) type communications occupy an important place. Unlike conventional cellular networks, where transmission between mobile equipment goes through the network infrastructure, D2D technology allows a direct connection between terminals without going through the base station (Chabbouh *et al.*, 2016). Over the years, traffic has experienced spectacular growth, and this trend is expected to continue in the years to come, as shown in Fig. (1) based on a report from Ericsson with the unit in Exabytes.

This results in an overload of the Base Station (BS). Due to this increasing load on the base station, the demand for energy increases (Randrianarison and Ramafiarisona, 2023). Part of the traffic must be offloaded from the base station in order to meet this high power requirement, and this is where D2D communication is essential because it enables devices to communicate with one another without

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passing through the base station, thus significantly reducing the load on the base station (Randrianarison and Ramafiarisona, 2023). However, the sharing of radio resources between classic cellular traffic and D2D flows within the same frequency band generates mutual interference that must be managed and mitigated (Tata, 2014). Among the approaches considered in the literature, the principle of "Resource Pooling," dynamically allocating frequency or time resources to cellular and D2D, combined with "adaptive power control" of terminals, seems promising to reduce this interference.

The objective of this study is, therefore, to analyze in depth the operation of Resource Pooling and adaptive power control techniques, as well as to evaluate their combined effectiveness in a context of mixed interference in 5G.

Review of the Literature

In this section, we will present the work carried out by other authors on the management of interference between cellular and D2D communications. Safdar *et al*. (2016) have proposed the use of three algorithms according to the type of situation in order to ensure the management of interference between cellular and D2D communication in the underlay case. The researchers focused solely on the management of uplink resources. They obtained good results. The algorithms used are as follows: The PPF1, PPF2, and Heuristic MAX-Capacity algorithms are efficient resource allocation algorithms that can be used in cellular networks coupled with D2D. The choice of algorithm to use depends on the specific needs of the network. They compared four heuristic subchannel allocation schemes. They found that the PPF1 and Heuristic Max Capacity schemes are quite complementary in terms of cellular capacity and fairness and that they are good candidates for future cellular systems.

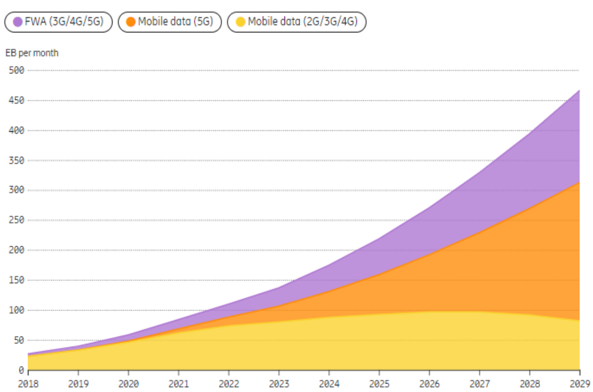

Fig. 1: Traffic trends by year according to Ericsson (Ericsson Mobility Report, 2024)

Giambene and Khoa have proposed methods regarding interference management based on non-cooperative game theory (Giambene and Khoa, 2018). They used the resource allocation and power management approach, all based on utility functions, while seeking the Nash equilibrium. Their work provided a very optimal working basis, on which we have relied more to produce research work. Resource allocation is done by taking into account the utility functions according to whether they are maximized or not, and similarly, the transmission powers are adjusted according to whether the utility function is also maximal. Their solution thus sought the Nash equilibrium by taking into account these two phases for an optimal solution.

Katsinis's work focuses on the joint management of uplink and downlink resource allocation in D2D communication (Katsinis *et al*., 2017). In order to achieve the intended objective more efficiently, they divided their approach into 2 sub-approaches: Power control and Channel assignment. To accomplish this objective, they used the new Hungarian algorithm in the uplink and downlink. By determining a set of ideal transmission powers, they demonstrated that the power allocation problem is a convex function with an optimization solution. Furthermore, the Hungarian method was refined to accomplish channel assignment for every cellular-D2D pair, and the system capacity matrix was obtained. The proposed JUAD scheme not only improves the total system capacity but also meets QoS requirements. Simulation results show that the performance of the proposed scheme for the joint uplink and downlink is better than the previous results obtained by the Hungarian algorithm used only in uplink or downlink. Xin Song *et al*. proposed "Joint Uplink and Downlink Resource Allocation for D2D Communications System" (Kai *et al*., 2018) focusing on both uplink and downlink. This algorithm reduces the complex channel allocation problem to a two-layer problem: The first layer allocates channels to cellular users, and the second layer allocates channels to D2D users. The algorithm uses matching game theory to find the best channel allocation for cellular and D2D users, taking into account interference between them.

Based on matching game theory and taking into account the characteristics of the 5G environment (Vu-Huu Kai *et al*., 2022), the authors proposed a two-layer QoE matching game algorithm, which divides the complex channel allocation problem into layers. First, the first layer of the cellular user channel allocation algorithm is established, and then the second layer of the D2D user channel allocation algorithm is established, thus forming the whole algorithm to solve the channel allocation problem for all users. During this process, user fairness and complex interference problems between users are fully taken into account, and the system's objective optimization function, i.e., the utility function, is improved. It is no longer a matter

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of blindly seeking high throughput but of taking into account the user's quality of experience.

In 2015, PEIYUE ZHAO investigated the performance of D2D communications but with small-scale Channel State Information (CSI) (Zhao, 2015). He analyzed existing Power Control (PC), Mode Selection (MS), and Resource Allocation (RA) approaches in terms of the required input parameters, focusing on large-scale fading and, finally, through his work, a new Binary Power Control and Matching Allocation which can increase the throughput significantly between cellular users and D2D users was proposed.

Interference Management

Interference management is one of the major challenges for D2D communication. This occurs because D2D applications implement a sharing mode that aims to increase spectral efficiency but which can cause interference to the network. Interference is also caused by the coexistence of CU and D2D pairs using the same cellular resources and D2D users (Tata, 2014).

Enabling D2D links within a cellular network poses a major threat of interference to the cellular links in the network. D2D links can cause interference between cellular users and D2D users, resulting in increased intra-cell interference.

Inter-cell interference is also possible with D2D communication underlaying cellular communication. Interference can be mitigated through mode selection, optimal resource allocation, and power control. Setting maximum transmit power limits for the D2D transmitter is an effective technique to limit interference between D2D users and cellular users.

Interference Scenarios in Underlay Inband Case

In the case of underlying D2D (Device-to-Device) communication in the cellular network, the existing LTE-A cells share the same cellular spectrum and coverage area with D2D equipment. In this condition, the same radio resource blocks (RBs) of cellular users are reused by D2D users, and it introduces undesirable interference (known as cross-tier interference) on one hand from cellular users to D2D users and on the other hand from D2D users to cellular users. Due to the high transmission power of the eNB (evolved Node B), D2D users experience significant interference when reusing downlink RBs. This results in poor performance of D2D systems, lowers SINR (Signal-to-Interference plus Noise Ratio), and makes it impossible to ensure the quality of D2D services.

Additionally, since uplink traffic loads and control signals are significantly lower than those of the downlink in cellular networks, reusing uplink RBs results in less undesired interference for D2D users. As a result, the uplink spectrum has less overall interference than the downlink one. When it comes to uplink resource sharing, it is evident that the cellular uplink user creates interference for the D2D receivers, while the D2D transmitter unintentionally interferes with the eNB. In the downlink scenario, the D2D transmitter is also the aggressor interfering with the cellular downlink user, and the eNB is the aggressor interfering with several D2D receivers. Additionally, D2D couples that concurrently share the same RBs in both uplink and downlink reuse scenarios experience mutual interference, also known as intra-tier interference. In order to avoid disturbing current cellular users, it is imperative that the interference caused by D2D users be reduced. The basic interference scenarios in the D2D-enabled cellular network are summarized in Table (1) (Tata, 2014).

System Assumptions

We are interested in the uplink data transmission in a D2D cellular network. We assume a single-cell environment, with a gNB at the center and several UEs distributed around it, as presented in Fig. (2). The UEs and the gNB are equipped with a single omnidirectional antenna. The system contains two types of UEs: Cellular UEs (CUEs) and D2D UEs. The CUEs communicate with the gNB, while the D2D UEs communicate directly with each other.

In this study, we will refer to the set of cellular users as M (m = 1,2,3,...M), the set of D2D users as K (k = 1,2,3,...K) and the channels or RBs as N (n = 1,2,3,...N).

Table 1: Interference scenarios

Case	Resource sharing direction	Aggressor	Victim	Type of Interference	Priority
1	UL	D2D Tx	eNB	Cross-tier	Yes
2	UL	CU	D2D Rx	Cross-tier	No
3	DL	D2D Tx	CU	Cross-tier	Yes
4	DL	eNB	D2D Rx	Cross-tier	No
5	UL/DL	D2D Tx	D2D Rx	Co-tier	No

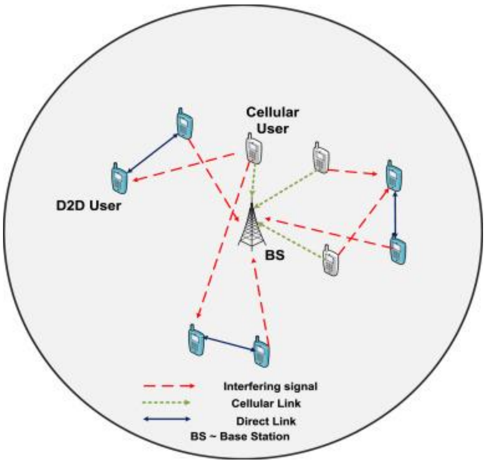

Fig. 2: System assumptions (Safdar *et al*., 2016)

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We also assume that the resources used in neighboring cells are different. This allows us to avoid other gNBs reusing the same resources. Hence, there is a certain frequency reuse distance D = R. Where R represents the cell radius, D is the frequency reuse distance. This precision is worth it because the proposed solution treats interference cases that only affect one cell.

In addition, the gNB has a limited number of orthogonal RBs (N) that it can allocate to cellular (M) and D2D (K) links. Cellular links each occupy a different RB, which eliminates interference. D2D links can share the available RBs with cellular links if they have been released, which allows for more efficient spectrum utilization. It is possible that the sum of M links and K links is greater than the Number of RBs N.

Furthermore, we assume in this study that cellular users have priority over D2D users. The SINR at the receiver of the i^{th} cellular or D2D link for the RB n assigned to this link can be defined as follows:

$$SINR_i^n = \frac{G_{ii}^n . P_i^n}{Interf\_cell * \; Interf\_D2D * Noise} \quad (1)$$

$$Interf\_cell = \sum Power * Gain_{cell} * Allocation_{cell} / \; G_{ii}^n . P_i^n \quad (2)$$

$$Interf_{D2D} = \sum Power * Gain_{D2D} * Allocation_{D2D} / \; G_{ii}^n . P_i^n \quad (3)$$

$Allocation_{cell}$: This is a matrix function that randomly allocates, taking as a parameter the Number of cellular users and the Number of resources.

$Allocation_{D2D}$: This is a matrix function that randomly allocates resources to D2D users, taking as parameters the Number of D2D users and the Number of available resources."

Problem Formulation

In this section, the focus is on managing the transmission power of UEs through joint power adaptation and resource management in order to minimize interference in an underlying (underlay) cellular network within a cell. Thus, we aim to minimize the total interference across all links in the network. Cellular links occupy different RBs, while D2D links share RBs with cellular links and among themselves. Interference arises because cellular resources (Zhao, 2015) are reused by D2D users, and uncontrolled UE power creates interference (Liu and Wang, 2015; Song *et al*., 2015).

We can view this problem as a mixed integer linear programming case based on power adaptation and resource pooling. The following conditions are then established:

- $Max \sum_i P_i R_i$
- $\sum_i P_i \leq P_{max}$ Constraint (1)
- $\sum_{ij} \text{xx}_{\{ij\}} \leq 1$ Constraint (2)
- $\sum_i P_i \, \text{x}_{\{ij\}} \leq P_{th,j}$ Constraint (3)
- $\text{x}_{\{ij\}} = \{0, 1\}$

where:

- P_i is the transmission power of user *i*
- R_i is the transmission rate or throughput of user *i*
- P_{max} is the maximum allowed transmission power
- $x_{\{ij\}}$ is a binary variable indicating if user i is using channel *j*
- $P_{th,j}$ is the interference power threshold on channel *j*

The goal of the solution is to maximize the overall system power and throughput in order to achieve better QoS. The throughput depends on the SINR of each user in the network:

- Constraint (1) ensures that the total transmission power does not exceed the maximum allowed power
- Constraint (2) ensures that a user can only use a single channel
- Constraint (3) ensures that the interference power on each channel does not exceed the threshold

To satisfy these constraints, we have opted to use power adaptation coupled with resource pooling to manage interference in the uplink.

Resource Pooling Coupled With Power Control Algorithm

The Resource Pooling algorithm is an optimization algorithm used to solve Mixed Integer Linear Programming (MILP) problems with resource constraints. It works by grouping similar resources into groups called "pools." Power adaptation is a technique used to improve the Quality of Service (QoS) of cellular communications. It involves adjusting the transmission power of base stations (gNB in 5G) and mobile terminals (UE) based on the distance between them and the radio environment. It involves adjusting the transmission power of base stations (gNB) or mobile terminals (UE) in order to minimize the impact of interference on other users.

Materials and Methods

Operating Principle

The power adaptation algorithm coupled with resource pooling is a technique that combines these two techniques to improve both QoS and spectral efficiency.

The power adaptation algorithm coupled with resource pooling works as follows:

1) The gNBs and UEs measure the received power and signal quality
2) The gNBs and UEs use these measurements to calculate the optimal transmission power
3) The guns and UEs exchange information on unused radio resources
4) The gNBs redistribute the unused radio resources to UEs that need them

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Algorithm

In order to provide a suitable solution, the proposed approach was inspired by the work done by Katsinis *et al*. (2017), Li *et al*. (2023), Chen *et al*. (2016), Ferdouse *et al*. (2017), who used power adaptation to reduce interference and resource pooling for resource allocation. We have combined two of these methods in view of the effectiveness they can have when coupled. We can also add that Djomadji *et al*. (2024) have used a genetic algorithm to implement mode selection in D2D communication for 5G cellular networks. Another interesting work related to D2D communications is the survey done by Gandotra and Jha (2016), which included the plus points it offers, and the key open issues associated with it like peer discovery, resource allocation, etc.

In this section, we propose the code for the operating principle of the proposed algorithm. It is important to note that we have chosen to couple the two methods because the interference problem is often due to the transmission power that will often disturb and play the role of a parasite with other links; but also, the inter-channel interference problem arises when D2D users reuse cellular resources. The operating principle of our algorithm is as follows:

```
▪ Begin
▪ # Initialized network parameters:
▪ * Number of cellular users: 80
▪ * Number of D2D pairs: 20
▪ * Number of resources: 100
▪
▪ # Random channel gain generation:
▪ * Cellular gains: between 0 and 400
▪ * D2D gains: between 0 and 100
▪
▪ # Noise modeling:
▪ * Cellular noise: Gaussian
▪ * D2D noise: Gaussian
▪
▪ # Resource allocation by resource pooling:
▪ * For cellular: random allocation
▪ * For D2D: sequential allocation
▪
▪ # Power control:
▪ * Initial cellular power: 900
▪ * Initial D2D power: 700
▪
▪ # Iteration loop:
▪ * 100 iterations
▪
▪ # Calculate SINR for cellular users:
▪ * For each cellular user:
▪     * Calculate signal
▪     * Calculate cellular interference
▪     * Calculate D2D interference
▪     * Calculate SINR
▪
▪ # Power adaptation:
▪ * If the average SINR is below 35 dB:
▪     * Increase cellular power
▪     * Decrease D2D power
▪ * If the average SINR is above 35 dB:
▪     * Decrease cellular power
▪     * Increase D2D power
▪
▪ # Calculate RB access success proportion:
▪ * Total Number of cellular users who could access a resource
▪ * Total Number of resources
▪
▪ # Calculate average throughput:
▪ * Average SINR for cellular users
▪
▪ # Record results:
▪ * SINR for each cellular user
▪ * RB access success proportion
▪ * Average throughput
▪
▪ END
```

The code starts by defining the network parameters. It then randomly generates the channel gains, noise, and initial resource allocations. The main iteration loop of the code runs 100 times. At each iteration, the code calculates the SINR for the cellular users. To calculate SINR, the code first calculates the signal, cellular interference, and D2D interference. The signal is calculated based on the user's power and channel gain. Cellular interference is calculated based on the power of other cellular users and their channel gains. D2D interference is calculated based on the power of D2D pairs and their channel gains. Once the SINR is calculated, the code adjusts the powers of the cellular and D2D users. If the average SINR is below 35 dB, the code increases the cellular power and decreases the D2D power. If the average SINR is above 35 dB, the code decreases the cellular power and increases the D2D power. Finally, the code calculates the RB access success proportion and the average throughput. The RB access success proportion is calculated based on the Number of cellular users who could access a resource. The average throughput is calculated based on the average SINR.

A few specifications need to be noted:

- The gains in the proposed algorithm are matrices that take the rows as the Number of cellular and D2D users and the columns as the Number of resources.
- The Gaussian noises in the algorithm are matrices that take the rows as the Number of cellular and D2D users and the columns as the Number of resources.
- We also have the D2D allocation and cellular allocation matrices that take the rows as the Number of cellular and D2D users and the columns as the Number of resources.
- The powers are vectors

Results and Discussion

Simulation Tool

The tool used for this simulation is the “MATLAB 2016a” software installed in “Windows 11” environment.

Simulation Parameters

In the MATLAB simulations, a number of parameters to carry out the work were used:

- A single cell was considered
- Frequency spectrum of B = 20 MHz
- The Number of resource blocs is NRb = 100

For The first test, the Number of cellular users was set at 80 and the Number of D2D users to 20.

- The cellular user transmit power is initialized to Pcell = 900 mw
- D2D user transmit power is initialized to Pd2d = 700 mw
- User earnings are allocated to users at random

To evaluate the proposed solution, the objectives are as follows:

- Plot cellular SINR as a function of Iterations.
- Plot the cellular_interference caused by D2D users as a function of iterations; to do this, we have considered the case where there are 20, 50, and 70 D2D users in the cell.
- Plot the interference_D2D caused by cellular users
- Plot the power of cellular and D2D users during and after adaptation
- Plot overall system throughput

Results and Discussion

After several simulations using MATLAB software, we obtained the following results:

- Graph of cellular SINR as a function of Iterations

In this graph, we have taken the case of 03 cellular users and studied the evolution of the SINR over 100 iterations. Reminder of the formula:

$$SINR_i^n = \frac{G_{ii}^n . P_i^n}{Interfcellular * \ InterfD2D * \ Noise} \quad (4)$$

For the graph of Fig. (3), we have found that after a few iterations, the SINR becomes constant and is indeed large.

We ran several tests repeatedly and were able to place users' overall SINR in the range [50; 92 dB]. For a 5G network, achieving a SINR is proof of very low latency and very high throughput. We can conclude that cellular users won't really have any difficulties in communicating:

- Graph of cellular interference caused by D2D users as a function of iterations

In this study, we took several cases in which we wanted to see how the Number of D2D users could negatively influence cellular users, who have priority.

The cases are as follows by considering Eq. (2) presented above:

- For D2D Users = 20

Interference produced by D2D users on cellular users is low. They are of the order of [-96; -84 dB]. Based on Fig. (4), we can see that a small number of users do not really influence the quality of the signal received by cellular users.

- For D2D Users = 50

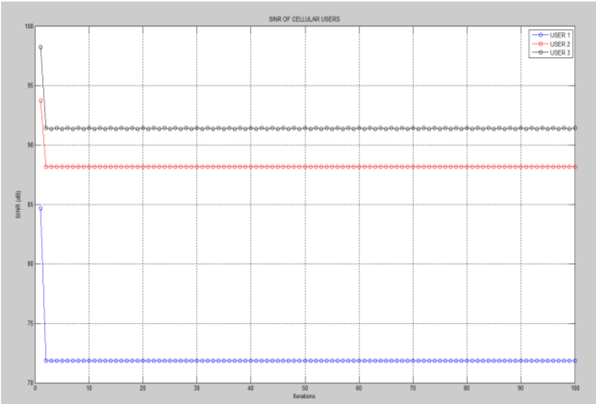

Fig. 3: SINR evolution for 3 cellular users

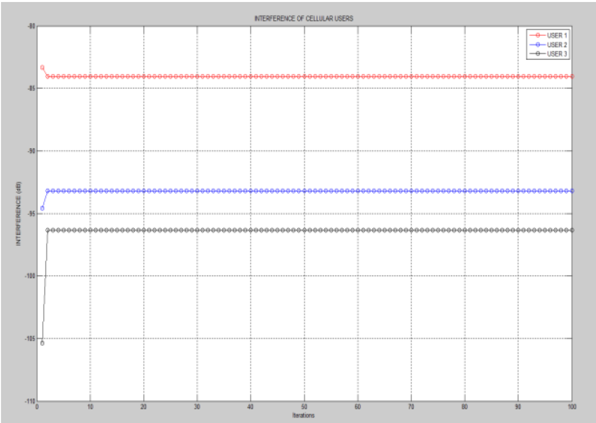

Fig. 4: Interference of cellular users case of 20 D2D users

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From Fig. 5, we can see that interference produced by D2D users on cellular users is still low for this case of 50 D2D users. They are of the order of [-95 dB; -87.5 dB]. Once again, despite the increase in the Number of D2D users, interference remains low. This is also due to the fact that the resource pooling algorithm has a predefined number of pools, which is a function of the Number of block resources allocated in a cell. We also assume that the Number of D2D users connects sequentially in the network.

- For D2D Users = 70

From Fig. (6), we can see that interference produced by D2D users on cellular users remains low. They are of the order of [-94 dB; -82 dB]. We would like to point out that these results are obtained randomly, as the algorithm randomly generates users' channel gains within the range set earlier.

In the end, having reviewed the various results obtained, we can say that D2D communication does not greatly harm cellular communication, which has priority. This demonstrates the robustness of the approach to cellular communication. However, the solution would not be effective if cellular communication, in turn, harmed D2D communication. So, it is important to take a look at D2D communication:

- Graph of D2D interference caused by cellular users

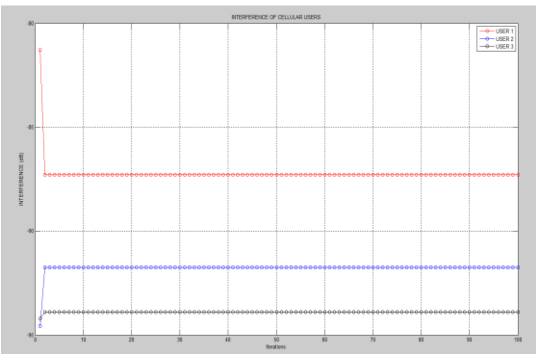

Fig. 5: Interference of cellular users case of 50 D2D users

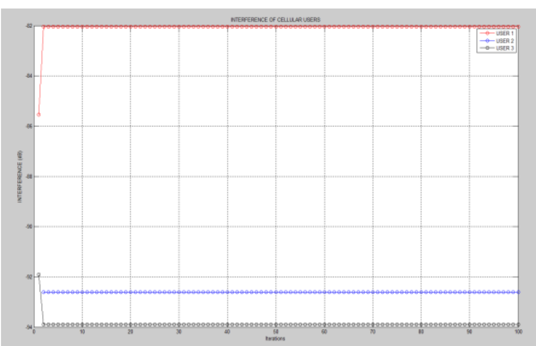

Fig. 6: Interference of cellular user's case of 70 D2D users

Here, we proposed to study the case of 03 D2D users, as shown in Fig. (7), with the iterations in x-axis and the interference level in y-axis for each user.

We can see that interference between the 03 D2D pairs is low. Their values are in the range [-102 dB; -95 dB]. Thanks to this estimate, we can say that the solution obtained does not disadvantage cellular users in the cell. Interference is controlled in both types of communication in the system and by the presented approach. Since the algorithm takes into account more than just the management of Resource Blocks, we have plotted the evolution of cellular and D2D user powers during power adaptation over 100 iterations.

- Cellular and D2D user power graphs during and after adaptation
  - P_cell = P_cell*5 linear if average SINR less than 35
  - P_cell = P_cell*0.001 linear if average SINR is greater than 35

The power graph for cellular users can be represented as follows in Fig. (8):

- P_D2D= P_D2D*0.001 linear if average SINR less than 35
- P_D2D= P_D2D*5 linear if the average SINR is greater than 35

The power graph for D2D users can be represented in Fig. (9), where the y-axis is D2D power, and X-axis represents the Number of iterations.

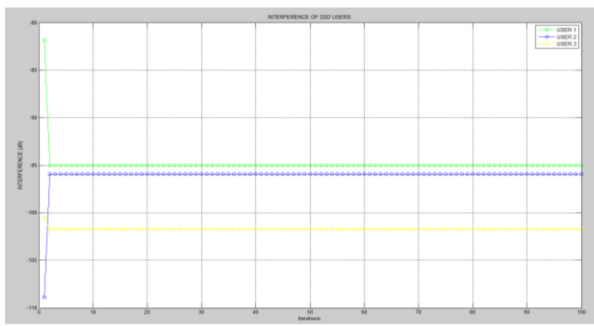

Fig. 7: Graph of D2D interference caused by cellular users with 03 D2D users

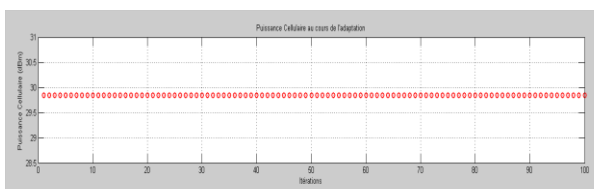

Fig. 8: Cellular power during adaptation

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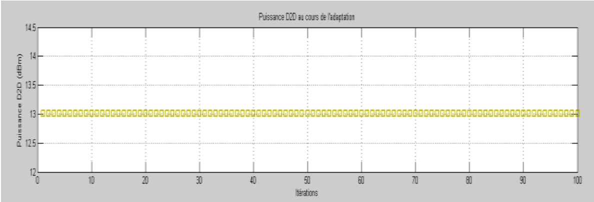

Fig. 9: D2D power during adaptation

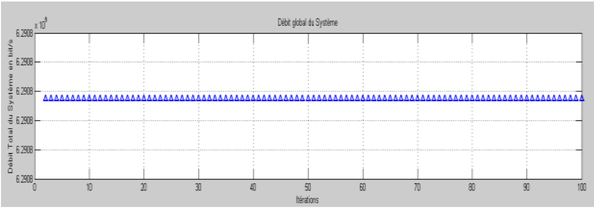

Fig. 10: Total system throughput

The proposed algorithm sets the cellular and D2D power values at 900 and 700 mW, respectively. During and after power adaptation, we find that the transmit powers of each type of user are adapted and decreased in order to obtain the cellular SINR, cellular interference, and D2D interference values we obtained above.

Cellular and D2D users transmit with 29.8 dBm and 13 dBm, respectively, during and after power adaptation.

- Overall system flow graph

$$Ri = \sum_{n \in N} \frac{R_i^n}{NbrUsers} = \quad (6)$$

To estimate overall system throughput, we produced the throughput curve for the previous 100 iterations. With a view to gauging what average throughput each user might have, we produced the following Fig. (10), where the y-axis represents the system's total throughput and the x-axis the Number of iterations.

We had an overall throughput of 6.29 Mbit/s. This is a good result, as it shows that most users have smooth communication, and the proportion of successful resource allocation is around 0.5.

Conclusion

At the end of this study where, we set out to propose an optimal interference management solution using Resource Pooling coupled with Power Adaptation, a goal of using a program that, on the one hand, uses pools resources and allocates them to cellular users first and then to D2D users was set. The aim was to reduce interference in the system.

In this study, first of all, the literature review on interference management in D2D in general and underlay inband in particular was presented. Then, the Resource Pooling method coupled with power adaptation was presented, followed by a proposed algorithm and its operating principle. Finally, we present the results obtained according to the parameters set above, resource pooling for dynamic allocation of time or frequency resources between cellular and D2D, and adaptive power control techniques adjusting emission levels according to perceived SINR. A crossover solution combining Resource Pooling allocation and SINR-based adaptive power control was proposed and evaluated by simulations in MATLAB.

The results obtained show significant gains in terms of average SINR, proportion of resources allocated to D2D flows, and aggregate throughput in the network, validating the effectiveness of the proposed approach to managing mixed cellular/D2D interference.

Although the proposed solution produced results which is reliable, it can still be improved, for example, by considering the following points:

- More dynamic allocation of resources according to each user's throughput demand
- Analysis of likely interference and allocation of resources accordingly
- Use of a queue to store potential D2D users to whom resources have not yet been allocated for communication

Analysis of Block resources that have been released and allocation of users in the queue.

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Author's Contributions

Eric Michel Deusom Djomadji: Participated in all experiments, defined the mathematical model, implemented the model in Matlab and contributed to the writing of the manuscript and supervised the work globally.

Arsene Mengoumou Abessolo: Participated in all experiments, defined the mathematic model, implemented the model in Matlab and contributed to the writing of the manuscript.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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