Two-Regimes Interference Classifier: an Interference-Aware Resource Allocation Algorithm

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***Abstract*—Performance of heterogeneous network is strongly limited by the interference due to multiple access points operating in the same geographical area, with overlapping service coverage. The common understanding is that interference, classically processed as additive noise, compromises the transmission and therefore must be ideally avoided or at least strongly limited. However, recent investigations in the domain of information theory and successive interference cancellation (SIC) techniques have proved that interference may not necessarily be treated as an opponent, but may become an ally. In this paper, we propose a novel interference aware resource management algorithm, where the system may only control its interference perception. In a system consisting of a couple of downlink users and access points with overlapping coverage, we aim to define the most spectral-efficient way to process interference at each receiver. Based on a 3-regimes interference classifier, both users in the system may either treat interference as noise, orthogonalize transmissions so that interference may be avoided, or cancel interference out of the received signal via SIC-based techniques. Our study shows that, when aiming at maximizing total spectral efficiency, ignoring or avoiding interference is not always the best option. Based on our theoritical study, we propose an interference classification algorithm, with only 2 admissible regimes for each user. Finally, we assess its notable performance improvement by simulation results.**

I. Introduction

Performance of heterogeneous networks is strongly limited by the interference of overlapping service coverage offered by access points operating in a common geographical area. Common understanding is that interference, which is classically processed as additive noise, compromises the performance and must be ideally avoided or at least strongly limited.

Therefore, a first approach to limit interference is orthogonalizing transmissions among interfering sources [1]. Such interference management is permitted by partial or full orthogonalization between competing interferers, as proposed by time sharing, frequency reuse or graph coloring [2].

However, in such resource allocation techniques, the resources are underexploited and the system suffers of poor spectral efficiency. An other set of interference mitigation technique, proposes to adapt transmission settings to the momentary communication context. Network MIMO [3], interference alignment [4] and power control techniques [5] are some of these.

While orthogonalization of resources drives to a sub-optimal system spectral efficiency, interference aware power balancing techniques reset the overall network interference pattern and consequently the victim interference perception [6] [7]. Although more powerful, these techniques suffer from a significant complexity and from vicious circle effects, due to users constantly readapting their power and changing the interference patterns [12]. Finally, most proposals dealing with interference in heterogeneous networks derive from the cognitive radio concept and dynamically allocate spectral and power resources to a set of UEs that overlap within the same geographical area [8].

Recent advances in the domain of information theory have shown that interference might not necessarily be an opponent, but may become an ally. The interference can be classified into 5 regimes, as in [9]. Intrinsic properties of interfering signals are exploited in order to judiciously process interference and achieve channel capacity [10]. The inherent complexity of this classification was reduced to a 3-regimes classifier in [11], in the case of 2 interfering cells. In such a context, the interference, may either be treated as noise, avoided by considering orthogonal transmissions or decoded and cancelled out of the useful signal via SIC-based techniques.

In this paper, we propose a novel approach of a classic RRM problem with 2 interfering cells, where the system deals with its perception of the interference and aims to maximize its total spectral efficiency. Indeed, we propose to adapt the perceived robustness of transmission at each receiver by adapting the reliability of the transmission according to both receivers interference perceptions. This way, we reduce the complexity of the optimization problem, by only allowing changes on the interference perception of each user. We leave unchanged the short-term power configuration and interference patterns. The optimization problem study reveals that, when maximizing the total spectral efficiency, interference does not have to be avoided. This leads finally to a reduced interference classification, with 2 regimes for each user, that can be exploited in more sophisticated multi-user optimization problems.

In Section II, we define the system model and the optimization problem to be solved. In Section III, we provide information about the 3-regimes classifier defined by Abgrall

[11]. In Section IV, we address the optimization, provide a theoritical analysis and extract a simplified 2-regimes classification algorithm. Finally, Section V provides numerical results that confirm the pertinence of the actual classifier and show its performance in terms of total spectral efficiency, compared to more traditional interference regimes.

II. System and optimization problem formulation

A. System definition

In this paper, the system consists of a set of two users (UE) and two base stations (BS), sharing the same geographical area and a same set of spectral resources. For the sake of simplicity, we have only considered, in this paper, the case where two interferers are matched together. Assuming $N > 2$ interferers have to be matched together leads to a lot more complex classifier, that is not being discussed nor detailed throughout this paper.

Both UEs and BSs are indexed by $i \in \{1, 2\}$. Each BS i is assigned to its UE i. For simplification, in the following, the pair BS i - UE i will be called user i. We consider a downlink interference broadcast channel, as depicted in Figure 1, with channel matrix $\mathcal{H}$:

$$\mathcal{H} = \begin{pmatrix} |h_{1,1}| & |h_{1,2}| \\ |h_{2,1}| & |h_{2,2}| \end{pmatrix} \tag{1}$$

Where $h_{i,j}$ refers to the channel between BS i and UE j. Noise instances $(z_i)_{i\in\{1,2\}}$ are assumed to be i.i.d. random realisations of a white gaussian noise process with zero mean and noise variance σ_n^2.

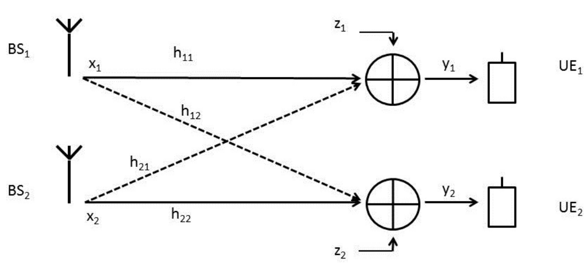

Fig. 1. A simple broadcast transmission scheme.

We assume that the transmission powers are fixed and denoted $\mathcal{P} = (p_1, p_2)$. According to the previous notations, we define $\forall i \in \{1, 2\}$, γ_i as the signal to noise ratio (SNR) perceived by i and δ_i, the INR perceived by i, related to the interference generated by $j \in \{1, 2\} \neq i$ as:

$$\gamma_i = \frac{p_i|h_{ii}|^2}{\sigma_n^2} \text{ and } \delta_i = \frac{p_j|h_{ji}|^2}{\sigma_n^2} \tag{2}$$

Finally, we denote, for each user i, O_i, the interference regime, i.e how the interference is treated by each user. The system can change its interference regimes, which lead to maximal spectral efficiencies $\mathcal{R} = (R_1, R_2)$ for each user. The interference can be processed, according to the 3-regimes classification introduced in [11]:

$$O_i = \begin{cases} 1 & \text{if Noisy} \\ 2 & \text{if Orthogonal Trans.} \\ 3 & \text{if SIC} \end{cases} \tag{3}$$

Details on each regime and their performance are provided in Section III.

B. Optimization problem formulation

In this paper, for given transmissions power and channels realisations, we seek the interference regimes for both users $\mathcal{O} = (O_1, O_2)$ that maximize the total spectral efficiency of the system, i.e. we define the following optimization problem:

$$\mathcal{O}^* = \left(\begin{pmatrix} O_1^* \\ O_2^* \end{pmatrix} \right) = \arg_{\mathcal{O}} \max_{\mathcal{O}} \left[\epsilon_{(O_1,O_2)} = R_1 + R_2 \right]$$
$$\text{s.t.} \begin{cases} R_1 = R_1^{max}(\mathcal{O}, \gamma_1, \gamma_2, \delta_1, \delta_2) \\ R_2 = R_2^{max}(\mathcal{O}, \gamma_1, \gamma_2, \delta_1, \delta_2) \end{cases} \tag{4}$$

Where $\forall i \in \{1, 2\}$, R_i^{max} denotes the maximal achievable rate, when the context of transmission is $(\gamma_1, \gamma_2, \delta_1, \delta_2)$ and the interference regime of both users is given by $\mathcal{O}$. Details on the R_i^{max} are provided in Section III.

In our optimization problem, the BSs cooperate and define the way interference is perceived at each receiver, adjusting individual spectral efficiency for each user in consequence, so that the total spectral efficiency is maximized. The number of admissible interference regimes $\mathcal{O}$ is finite, which leads to a problem that necessarily admits at least one optimal solution. The transmission powers, SNRs and INRs remain unchanged, which does not lead to classical complications (computing equilibrium of the game, convergence of an iterative approach,...) related to multi-user power control games, such as ping-pong effects, for example.

III. The 3-regimes interference classifier

In this section, we detail each interference regime and its limitations. We assume that the interference regime is described from the point of view of user $i \in \{1, 2\}$, where $j \in \{1, 2\} \neq i$ corresponds then to the other user.

A. The weak interference regime : Noisy

The first interference regime ($O_i = 1$) is the noisy interference regime: the in-band interference is not decoded by the receiver, but ignored and treated as an additional source of noise. According to [9], this happens in case of *weak* interference, i.e. $\alpha = \frac{log_2(\delta_i)}{log_2(\gamma_i)} < \frac{1}{2}$. We reformulate this constraint, as in [11], by stating that the user i must decode the incoming signal, in presence of noise and interference, which means that the channel must not be in outage and the maximal spectral efficiency for user i is then:

$$R_i^{max,i} = \begin{cases} \log_2\left(1 + \frac{\gamma_i}{1+\delta_i}\right) & \text{if } O_j \neq 2 \\ \frac{1}{2}\left[\log_2(1+\gamma_i) \right. \\ \left. + \log_2\left(1 + \frac{\gamma_i}{1+\delta_i}\right)\right] & \text{if } O_j = 2 \end{cases} \tag{5}$$

B. The strong interference regime : SIC

The second interference regime ($O_i = 3$) corresponds to a *strong* interference regime, where in-band interference can be decoded by the receiver, and cancelled out from the useful signal. According to [9], this happens, when $\alpha = \frac{log_2(\delta_i)}{log_2(\gamma_i)} > 2$. As in [11], we reformulate this constraint and state that the receiver UE i must be able to decode the interference due to BS $j \neq i$ without outage, i.e. the maximal spectral efficiency for user j is then constrained by:

$$R_j^{max,i} = \log_2\left(1 + \frac{\delta_i}{1+\gamma_i}\right) \tag{6}$$

The user i must then decode the incoming signal, in presence of noise only (since interference has been cancelled out by SIC), which immediately leads to:

$$R_i^{max,i} = \log_2\left(1 + \gamma_i\right) \tag{7}$$

C. The in-between : orthogonal transmission

The third interference regime ($O_i = 2$) applies to cases where interference can not be decoded and is harming the transmission performance. According to [9] and [11], it corresponds to scenarios where $\frac{1}{2} < \alpha = \frac{log_2(\delta_i)}{log_2(\gamma_i)} < 2$. In such a context, the system can avoid the interference, at the cost of a halved spectral efficiency for each user, by splitting available spectral resources between both transmissions. Hereafter, we assume that spectral resources are shared and equally distributed between both transmissions, i.e. the maximal spectral efficiency for user i is then:

$$R_i^{max} = \frac{1}{2}\log_2\left(1 + \gamma_i\right) \tag{8}$$

D. Formulation of the different coupled regimes and their constraints

According to the previous sections, we can define 3 regimes for each pair source-destination, and their constraints on the spectral efficiencies of both users. This leads to 9 possible regimes (O_1, O_2), as summed up in I. Since some configurations are symmetric, only 6 regimes were listed in the following table.

TABLE I
SUMMARY OF REGIMES AND CONSTRAINTS

(O_1, O_2)	Constraint $R_1^{max}(O_1, O_2)$	Constraint $R_2^{max}(O_1, O_2)$
$(1,1)$	$\log_2\left(1+\frac{\gamma_1}{1+\delta_1}\right)$	$\log_2\left(1+\frac{\gamma_2}{1+\delta_2}\right)$
$(1,2)$	$\frac{1}{2}\log_2\left(1+\frac{\gamma_1}{1+\delta_1}\right) + \frac{1}{2}\log_2\left(1+\frac{\gamma_1}{1+\delta_1}\right)$	$\frac{1}{2}\log_2\left(1+\frac{\gamma_2}{1+\delta_2}\right)$
$(1,3)$	$\min\left[\log_2\left(1+\frac{\gamma_1}{1+\delta_1}\right), \log_2\left(1+\frac{\delta_2}{1+\gamma_2}\right)\right]$	$\log_2(1+\gamma_2)$
$(2,2)$	$\frac{1}{2}\log_2(1+\gamma_1)$	$\frac{1}{2}\log_2(1+\gamma_2)$
$(2,3)$	$\min\left[\frac{1}{2}\log_2\left(1+\frac{\gamma_1}{1+\delta_1}\right), \frac{1}{2}\log_2\left(1+\frac{\delta_2}{1+\gamma_2}\right)\right]$	$\log_2(1+\gamma_2)$
$(3,3)$	$\min\left[\log_2(1+\gamma_1), \log_2\left(1+\frac{\delta_2}{1+\gamma_2}\right)\right]$	$\min\left[\log_2(1+\gamma_2), \log_2\left(1+\frac{\delta_1}{1+\gamma_1}\right)\right]$

For any given $(\gamma_1, \gamma_2, \delta_1, \delta_2$, we have finally defined the total spectral efficiency that the system can achieve with the interference regime (O_1, O_2), as $\epsilon_{(O_1,O_2)} = R_1^{max}(O_1, O_2) + R_2^{max}(O_1, O_2)$.

IV. Solving the optimization problem

Since there is a limited number of admissible actions for $\mathcal{O} = (O_1, O_2)$, an attainable maximum $\mathcal{O}^*$ necessarily exists. Let us first define the following operator, $\triangleright$, where $(O_1, O_2) \triangleright (O_1', O_2')$ means that the interference regime (O_1, O_2) offers a better maximal total spectral efficiency than (O_1', O_2'), i.e.:

$$\epsilon_(O_1, O_2) \geq \epsilon_(O_1', O_2')$$
$$\text{with} \begin{cases} \epsilon_(O_1, O_2) = R_1^{max}(O_1, O_2) + R_2^{max}(O_1, O_2) \\ \epsilon_(O_1', O_2') = R_1^{max}(O_1', O_2') + R_2^{max}(O_1', O_2') \end{cases}$$

A. A first analysis leads to simplifications

According to optimization problem 4, we seek the interference regime $\mathcal{O}$ that maximizes the total spectral efficiency of the system. Among all 9 possible combinations, described in Table I and for any channel/power configuration, we distinguish 4 regimes of interest and 5 regimes always outperformed by at least one of the 4 regimes of interest. The following 3 propositions allow for simplifications.

Proposition IV.1. *For any given SNR/INR configuration, (2,1) and (1,2) are outperformed by either (2,2), (1,1), (3,1) or (1,3).*

Proof. All elements of proof have been extensively detailed in a complementary paper [13]. □

Proposition IV.2. *When the interference can be decoded and cancelled at one side, there is no interest for the interferer, whose interference is cancelled, to limit its transmission by using half of the resources. As a consequence, for any given SNR/INR configuration, (2,3) and (3,2) are respectively outperformed by (1,3) and (3,1).*

Proof. As before, refer to [13]. □

Proposition IV.3. *In order to maximize the total spectral efficiency, the system has more interest in a SIC-based configuration, rather than a full-orthogonalization one, i.e., for any given SNR/INR configuration, (2,2) is outperformed by either (3,1) or (1,3).*

Proof. As before, refer to [13]. □

As a consequence of the 3 previous propositions, we show that the study may be limited to only 4 regimes of interest: (1,1), (1,3), (3,1) and (3,3). This leads to a first interesting conclusion: when the system aims to maximize its total spectral efficiency, no user implements a $(2, .)$ or $(., 2)$ strategy. The system does not have to avoid the intereference, by implementing orthogonal transmissions. On the contrary, interference remains and is either treated as noise or eliminated, by implementing SIC-based strategies.

B. Defining best performance regions for each regime

In this section, we focus on defining criterias on $(\gamma_1, \gamma_2, \delta_1, \delta_2)$ that immediately tell what is the best regime among (1,1), (1,3), (3,1) and (3,3), in terms of total spectral efficiency performance, and what the performance of such a regime is. Let us first consider the two following propositions.

Proposition IV.4. $(1,1)$ *is the best interference regime if and only if* $(\gamma_1, \gamma_2, \delta_1, \delta_2)$ *verify the two following statements:*

$$\begin{cases} \gamma_1 \geq (1+\delta_1)\delta_2 \\ \gamma_2 \geq (1+\delta_2)\delta_1 \end{cases}$$

Proof. Refer to [13]. □

Proposition IV.5. $(3,3)$ *is the best interference regime if and only if* $(\gamma_1, \gamma_2, \delta_1, \delta_2)$ *verify the four following statements:*

$$\begin{cases} \gamma_1 \leq \delta_2 \\ \gamma_2 \leq \delta_1 \\ (1+\gamma_1)(1+\gamma_2) \leq (1+\delta_1)\left(1+\frac{\delta_2}{1+\gamma_2}\right) \\ (1+\gamma_1)(1+\gamma_2) \leq (1+\delta_2)\left(1+\frac{\delta_1}{1+\gamma_1}\right) \end{cases}$$

Proof. Refer to [13]. □

With the two previous propositions, we have defined two criteria for either $(1,1)$ or $(3,3)$ being the best interference regime. When $(\gamma_1, \gamma_2, \delta_1, \delta_2)$ does not verify any of the two previous propositions, then the best interference regime is either $(1,3)$ or $(3,1)$.

Proposition IV.6. *When* $(\gamma_1, \gamma_2, \delta_1, \delta_2)$ *does not satisfy the conditions of either Proposition IV.4 or Proposition IV.5, then:*

$$(1,3) \triangleright (3,1) \\ \Leftrightarrow \begin{cases} [\gamma_2 \geq \delta_1 \text{ and } \gamma_2 \geq \gamma_1 + (\delta_1 - \delta_2)] \\ \text{or } [\gamma_2 \leq \delta_1 \text{ and } (1+\gamma_1\delta_1)\gamma_2\delta_2 \geq (1+\gamma_2+\delta_2)\gamma_1\delta_1] \end{cases}$$

C. Proposed interference classifier algorithm

Based on the previous propositions, we describe in Figure 2, the following classification algorithm, with only 2 regimes for each user. The algorithm first checks the appartenance to the best performance regions related to $(1,1)$ and $(3,3)$. If it turns out that $(\gamma_1, \gamma_2, \delta_1, \delta_2)$ does not satisfy the conditions of either Proposition IV.4 or Proposition IV.5, then the algorithm checks which one performs the best between $(1,3)$ and $(3,1)$, according to Proposition IV.6.

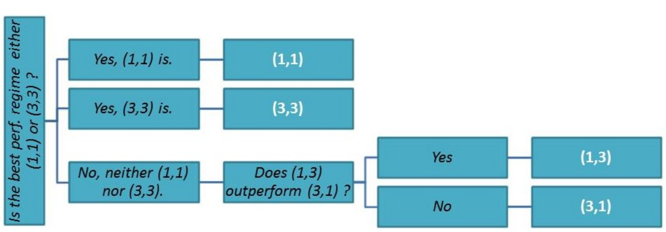

Fig. 2. A low-complexity algorithm: defining the best performance region for each regime of interest

V. Simulations, numerical results and discussions

A. Numerical confirmation of best performance regions

In this section, simulations results show the pertinence of our low-complexity classifying algorithm. For the sake of simplicity, we have fixed arbitrary values for INRs δ_1 and δ_2 in the following, such that $2\delta_1 = \delta_2 = 4$. Sets of values for γ_1 and γ_2 are defined as linear spaced sets consisting of $N = 50$ elements, such that $\gamma_1 \in [\epsilon, \frac{3}{2}(1+\delta_1)\delta_2]$ and $\gamma_2 \in [\epsilon, \frac{3}{2}(1+\delta_2)\delta_1]$. The minimal value for SNRs, ϵ, is set to 0.01. As a comparison, for each combination $(\gamma_1, \gamma_2, \delta 1, \delta_2)$, the best interference regime (O_1^*, O_2^*) is selected according to our classification algorithm. At the same time, we run a brute-force algorithm, testing all combination and returning the best performing regime among all 9 possible ones. The simulations show a perfect match and return Figure 3, showing the best performance regions for each regime.

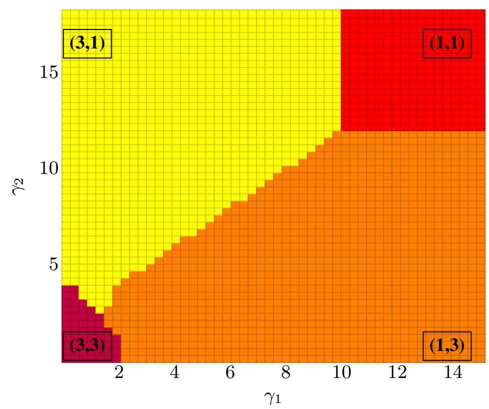

Fig. 3. Best performance regions related to each regime, with varying values of γ_1 and γ_2 and fixed δ_1 and δ_2

As expected, the $(1,1)$ regimes performs the best when both SNRs are strong compared to the INRs. A $(3,3)$ regime is prefered when both SNRs are weak compared to the INRs. In the remaining cases, when user 1 (resp. 2) has a weak SNR γ_1 (resp. γ_2) compared to SNR γ_2 (resp. γ_1), the best performance regime is, as expected, $(3,1)$ (resp. $(1,3)$).

B. Performance comparison

In this section, we take a glance at the potential performance benefit that could be provided by such a classifier. We compare its performance in terms of total spectral efficiency to the actual performance one could obtain with a system forcing interference to be treated as noise, in any configuration. To do so, we define the following performance criterion α, which shows the performance improvement offered to the system, compared to the $(1,1)$ regime:

$$\alpha(\gamma_1, \gamma_2, \delta_1, \delta_2) = \frac{R_{sm}(\gamma_1, \gamma_2, \delta_1, \delta_2) - R_{f11}(\gamma_1, \gamma_2, \delta_1, \delta_2)}{R_{f11}(\gamma_1, \gamma_2, \delta_1, \delta_2)} \tag{9}$$

Where $R_{sm}(\gamma_1, \gamma_2, \delta_1, \delta_2)$ is the total spectral efficiency, related to the best interference regime (O_1^*, O_2^*) defined by our classifier and $R_{f11}(\gamma_1, \gamma_2, \delta_1, \delta_2)$ is the total spectral efficiency offered by a system forcing a $(1,1)$ regime for any configuration.

Figure 4 shows the numerical estimation of the α criterion for the same fixed values of (δ_1, δ_2) and the same sets of values for (γ_1, γ_2) that we defined previously. It shows that, for any configuration, the optimal interference regime selected by our classifier performs just as well (if $\mathcal{O}^* = (1,1)$) or better than the forced $(1,1)$ regime. The performance is the same when $(O_1^*, O_2^*) = (1,1)$, but in the remaining cases, SIC is implemented at least at one receiver: some interference can be cancelled out and as a direct consequence, (O_1^*, O_2^*) strictly outperforms $(1,1)$. The potential gain is quite significant, especially when SNRs values γ_i become low compared to INRs δ_i.

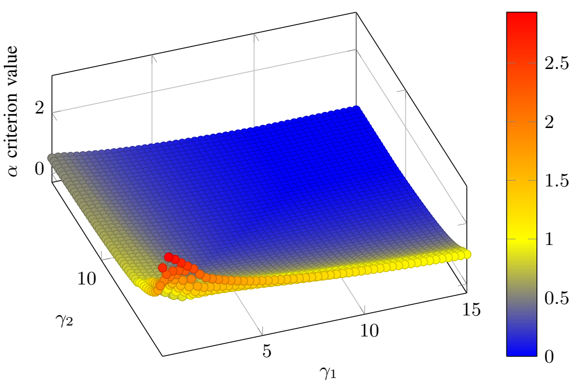

Fig. 4. Performance comparison between our smart classifier and a forced (1,1) - α criterion for varying values of γ_1 and γ_2 and fixed δ_1 and δ_2

From the previous, we conclude that the system has great interest in being able to classify its interference and treat it properly, rather than ignoring it and treating it as additive noise. As a reminder, Proposition IV.3 also showed that the performance of a system avoiding interference at all cost by othogonalization (i.e. forcing a $(2,2)$ configuration) was also outperformed by our smart classifier. Satisfying total spectral efficiency can still be obtained via SIC techniques, even when the interference becomes *strong* for at least one user, as shown in 5. For this reason, we might change our perception of the interference: interference does not necessarily have to be avoided or at least strongly limited, the system is able to efficacely cope with *strong* interference, thanks to SIC techniques.

VI. Conclusion

In this paper, we investigate a novel interference-aware RRM technique for wireless cellular heterogeneous networks, based on interference perception. A classification algorithm is derived from our theoritical study and numerical results show how the system can overcome the traditional limiting performance tradeoff between in-band interference and total spectral efficiency. Our low-complexity interference classifier operates with only two regimes for each user. We show that this classifier can increase the total spectral efficiency of

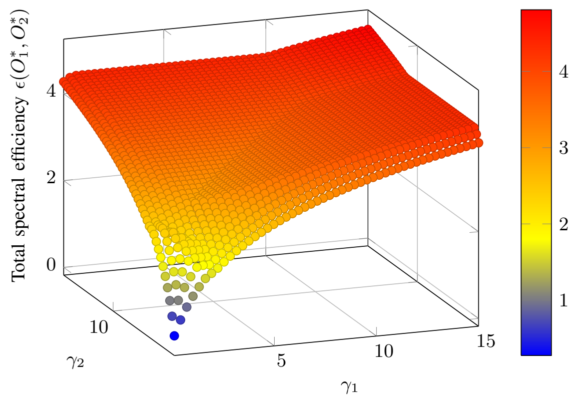

Fig. 5. Total spectral efficiency of our classifier for varying values of γ_1 and γ_2 and fixed δ_1 and δ_2

two overlapping cells, without changing the short-term power configuration and interference patterns.

Future work will further investigate an extension of the problem with multiple destinations for each source. It leads to a matching problem where in-band interferers have to be coupled in a smart way, knowing that the interference perception is defined according to a more complex classifier, slightly different than the presented classifier. Finally, allowing users to switch APs, especially in SNR/INR cases where INRs are extremely good compared to SNR, may also offer an additional degree of freedom that could be exploited.

VII. Acknowledgment

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References

[1] Gesbert, D., Kiani, S. G., & Gjendemsj, A. (2007). Adaptation, coordination, and distributed resource allocation in interference-limited wireless networks. *Proceedings of the IEEE, 95(12), 2393-2409.*

[2] Xiang, Y., Luo, J., & Hartmann, C. (2007, April). Inter-cell interference mitigation through flexible resource reuse in OFDMA based communication networks. *In European wireless (pp. 1-4).*

[3] Andrews, J. G., Choi, W., & Heath, R. W. (2007). Overcoming interference in spatial multiplexing MIMO cellular networks. *Wireless Communications, IEEE,14(6), 95-104.*

[4] Gomadam, K., Cadambe, V. R., & Jafar, S. A. (2008, November). Approaching the capacity of wireless networks through distributed interference alignment. *In Global Telecommunications Conference, 2008. IEEE GLOBECOM 2008. IEEE(pp. 1-6). IEEE.*

[5] Shah, V., Mandayam, N. B., & Goodman, D. J. (1998, September). Power control for wireless data based on utility and pricing. *In Personal, Indoor and Mobile Radio Communications, 1998. The Ninth IEEE International Symposium on (Vol. 3, pp. 1427-1432). IEEE.*

[6] Sahin, O., Erkip, E., & Goodman, D. (2006, May). Iterative Power Control for Multimedia Wireless Communications. *In Acoustics, Speech and Signal Processing, 2006. ICASSP 2006 Proceedings. 2006 IEEE International Conference on (Vol. 4, pp. IV-IV). IEEE.*

[7] Holliday, T., Bambos, N., Glynn, P., & Goldsmith, A. (2003, October). Distributed power control for time varying wireless networks: Optimality and convergence. *In PROCEEDINGS OF THE ANNUAL ALLERTON CONFERENCE ON COMMUNICATION CONTROL AND COMPUTING (Vol. 41, No. 2, pp. 1024-1033). The University; 1998.*

[8] De Domenico, A., Strinati, E. C., & Di Benedetto, M. G. (2012). A survey on MAC strategies for cognitive radio networks. *Communications Surveys & Tutorials, IEEE, 14(1), 21-44.*

[9] Etkin, R. H., Tse, D. N., & Wang, H. (2008). Gaussian interference channel capacity to within one bit. *Information Theory, IEEE Transactions on, 54(12), 5534-5562.*

[10] Shang, X., Chen, B., Kramer, G., & Poor, H. V. (2010). Capacity regions and sum-rate capacities of vector Gaussian interference channels. *Information Theory, IEEE Transactions on, 56(10), 5030-5044.*

[11] Abgrall, C. (2009). Resource allocation in dense wireless communication networks. *Thesis Manuscript.*

[12] Abgrall, C., Strinati, E. C., & Belfiore, J. C. (2010, September). Distributed power allocation for interference limited networks. *In Personal Indoor and Mobile Radio Communications (PIMRC), 2010 IEEE 21st International Symposium on(pp. 1342-1347). IEEE.*

[13] M. De Mari, E. Calvanese Strinati and M. Debbah, "'Elements of Proof - Two-regimes interference classifier: an interference-aware resource allocation algorithm"'. Available: https://docs.google.com/file/d/0B-8455Wl-SEiObE5xMWxRZGpyc28