Jamming in wireless networks with cooperative jammers

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Abstract: The problem of jamming plays a very important role in ensuring the quality and security of wireless communications, especially now when wireless networks are quickly becoming ubiquitous. Since jamming phenomenon can be considered as a game where a player (say, jammer) is playing against a user (transmitter), game theory is an appropriate tool for dealing with the jamming problem. In this paper we study how increasing number of jammers impacts the game. Namely, we consider plots with M jammers and as an objective function to the user we consider SINR and Shannon capacity. For both objective functions we have shown that the jammers employ time sharing strategies to bring the maximal harm and we produce a finite step algorithm allowing to find the saddle point in closed form.

1 The Game

The concept of jamming plays a very important role in ensuring the quality and security of wireless communications, especially now when wireless networks are quickly becoming ubiquitous. Although the recent literature covers a wide variety of jamming problems [1], [2],[4], [5], [6], [11], [12], the investigation of optimal jamming and anti-jamming strategies for SINR objective function is missing.

Since jamming phenomenon can be considered as a player (say, jammer) playing against a user (transmitter), game theory is an appropriate tool for dealing with the jamming problem. In this paper we study how increasing number of jammers impacts the game. Namely, we consider plots with one and two jammers and as an objective function to the user we consider SINR. We show that in all the scenarii the jammers equalize the quality of the best sub-carriers for transmitter on as low level as their power constraint allows, meanwhile the user distributes his power among these jamming sub-carriers, and in two jammer case the jammers employ time sharing strategies to bring the maximal harm.

The SINR as an objective function in the power control game was also considered in [3, 8]. In [3] the authors have analysed the optimization and non-cooperative game scenarii in the absence of jamming. In [8] all users have a single common channel and choose between several base stations.

We note that in the regime of low SINR the present objective can serve as an approximation to the Shannon capacity. A central motivation to consider SINR as an objective function is that current technology for voice over wireless does not try to achieve Shannon capacity but rather uses given codecs that can adapt the transmission rate to the SINR; these turn out to adapt the rate in a way that is linear in the SINR over a wide range of throughput. The SINR has therefore been used very often to represent directly the throughput (see [9, 10]). The validity of this can be seen e.g. in [7, p. 151, 222, 239]. As we see from [7, Fig. 10.4, p. 222], the ratio between the throughput and the SINR is close to a constant throughout long range of bit rates. For example, between 16Kbps and 256Kbps, the maximum variation around the median value is less than 20%.

In the jammer scenario one user (transmitter) should assign different power levels for different sub-carriers to maximize the objective function v meanwhile the other users (M jammers) want to hamper the transmitter jointly by minimizing this objective function. The strategy of transmitter is $T = (T_1, \dots, T_n)$ with

$$T_i \geq 0, i \in [1, n]$$

such that

$$\sum_{i=1}^{n} T_i = \bar{T},$$

where $\bar{T} > 0$ is the total available power for a transmission slot, n is the number of sub-carriers and T_i is the power level assigned for sub-carrier i.

The strategy of jammer m ($m \in [1, M]$) is $J^m = (J_1^m, \dots, J_n^m)$ with

$$J_i^m \geq 0, i \in [1, n]$$

and

$$\sum_{i=1}^{n} J_i^m = \bar{J}^m,$$

where $\bar{J}^m > 0$ is the total jamming power of jammer m.
As the objective function v to the transmitter we consider either his SINR:

$$v(T, (J^1, \dots, J^M)) = \sum_{i=1}^{n} \frac{\alpha_i T_i}{N^0 + \sum_{m=1}^{M} \beta_i^m J_i^m},$$

or Shannon capacity

$$v(T, (J^1, \dots, J^M)) = \sum_{i=1}^{n} \ln \left(1 + \frac{\alpha_i T_i}{N^0 + \sum_{m=1}^{M} \beta_i^m J_i^m}\right),$$

where α_i and $\beta_i^m > 0$ are fading channel gains of transmitter and jammer m for sub-carrier i, N^0 is the the background noise. We assume that all the fading channel gains α_i and β_i^m, the background noise level N^0, the total powers $\bar{T}$ and $\bar{J}^m$ are known to all the players.

For both objective functions we have shown that the jammers employ time sharing strategies to bring the maximal harm and we produce a finite step algorithm allowing to find the saddle point in closed form.

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