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BLIND DETECTION IN A NONCOHERENT ASYNCHRONOUS DHA FH OFDMA SYSTEM

Introduction

Dynamic Hopset Allocation Frequency Hopping OFDMA (DHA FH OFDMA) has been initially proposed in [1]. Since then a number of modifications has been considered. Noncoherent DHA FH OFDMA with threshold reception seems the most promising one since it is much less vulnerable to multitone jamming than the conventional FH OFDMA. However in [1] it has been assumed that all the signals from all users have the same power at the receiver side and the received signal is affected only by multiple access interference (i.e. signals transmitted by the other users) and additive white Gaussian noise. Although such an assumption simplifies the analytical treatment of the system in question (nevertheless this problem remains a cumbersome one) it is true only for a system with ideal channel state information (CSI) at the transmitter. Moreover, the maximum power of the transmitted signal is to be sufficient to ensure the desired power of the signal at the receiver side no matter how low the transfer ratio of the subchannel in use is. However, in real life applications the power of the transmitter is limited and ideal CSI is not available at the transmitter side (in fact ideal CSI is not available at the receiver side as well). Therefore although the aforementioned assumption can be considered as the first step in the analytical treatment of the system under consideration it doesn't clarify the perspective of the implementation of the aforesaid technique in real-life applications. This paper deals with the problem of proposing a modification of the classical DHA FH OFDMA model with noncoherent threshold reception with the aim of designing a jamming-proof system that need not use CSI knowledge and power control. In what follows several system models complying with the aforesaid requirements will be proposed.

Blind detection: decision making and performance criterion

In what follows two detection strategies will be considered. Within the scope of the first detection strategy the receiver chooses the greatest power subchannel and accepts the symbol corresponding to it (let us further on refer to this strategy as Strategy 1 (ST1)). Within the scope of the second detection strategy we will assume that the output of a certain subchannel corresponds to the signal sent by an active user only if it is k times greater than the background noise power. Therefore the value $P_t = kN$ (where k is the threshold coefficient value and N is the background noise power) is a threshold enabling us to use the reception rule stated in [1]: "if decision crossing is detected in only one subchannel a symbol corresponding to it is accepted. Otherwise an erasure decision is taken". Let us further on refer to this strategy as Strategy 2 (ST2).

Let us now consider the aforementioned decision procedure in information theory terms. From the information theory point of view a DHA FH OFDMA system using decision strategy 2 is just a q-ary discrete channel with erasures. In order to find the channel capacity of this channel we shall use the following technique: the channel under consideration (let us designate it by C0) will be represented as a serial concatenation of a q-ary discrete symmetric channel (let us designate it by C1) and a q-ary erasure channel (let us designate it by C2). Note that since C1 and C2 are independent the probability of error $\tilde{p}_e$ that describes C1 is given by

$$\tilde{p}_e = \frac{p_e}{1-p_x}$$

The channel capacity of channel C1 is given by

$$C_e = \log_2 q + \left(\left(1-\frac{p_e}{1-p_x}\right)\log_2\left(1-\frac{p_e}{1-p_x}\right)\right) + \left(\frac{p_e}{1-p_x}\log_2\left(\frac{p_e}{1-p_x}\right)\right) - \left(\frac{p_e}{1-p_x}\log_2(q-1)\right) \quad (1)$$

therefore the channel capacity of the channel C0 is given by $C_C = C_e(1-p_x)$ (see [2]) and therefore:

$$C_c = \left(\left(1-p_x\right)\log_2 q\right) + \left(\left(1-p_e\right)\log_2\left(1-\frac{p_e}{1-p_x}\right)\right) + \left(p_e \log_2\left(\frac{p_e}{1-p_x}\right)\right) - \left(p_e \log_2\left(q-1\right)\right) \quad (2)$$

Note that both p_x and p_e depend on the number of active users *K*, the overall number of subchannels available to the active users *Q*, the number of subchannels allocated to each user *q*, *SNR* and the value of the threshold coefficient *k*. Thus if all the parameters but the last one are fixed it is reasonable to choose *k* that maximizes C_c. The obtained value R_m is the maximum possible transmission rate (MPTR) of reliable data transmission (the term "reliable" has the same meaning here as in [3]) in the system under consideration and is given by:

$$R_m = \max_k\left(C_c\left(p_e(k), p_x(k)\right)\right)$$

As for the decision strategy 1 the resulting system is just a q-ary discrete symmetric channel with probability of error p_e.Thus its channel capacity is given by

$$C_c = \log_2 q + \left(\left(1-p_e\right)\log_2\left(1-p_e\right)\right) + \left(p_e \log_2\left(p_e\right)\right) - \left(p_e \log_2\left(q-1\right)\right)$$

Note that in this case C_c coincides with R_m.

Unfortunately probabilities of error and erasure depend on the distribution of the subchannels' transfer ratios. Thus the effectiveness of the proposed strategies can be evaluated only by means of simulation.

Simulation

An asynchronous DHA FH OFDMA system with noncoherent reception is considered. We assume that the overall number of subchannels is 4096, which means that $Q = 3276$ are available to the active users. Each user is allocated q=2 subchannels at a time. The channel in use is assumed to correspond to the typical urban channel model from the 3GPP LTE standard. The speed of each user is randomly chosen from the array $V = [40, 50 \ldots 200]$ km/h. As has already been mentioned, we assume that all transmissions are uncoordinated and no power control is used. The background noise level is to be described by the SNR which is given by $SNR = 10\log_{10}\frac{P_t}{N}$ where P_t is the transmitted signal's power and *N* is the average noise power. In our simulation we shall use SNR=15 dB. Hereinafter we shall consider two cases. In the first case the number of active users is *K*=100. In the second case we shall assume *K*=200.

A twofold increase of the number of active users can be interpreted in two ways. On the one hand, it can be interpreted as a result of the authorized users' activity. Therefore our analysis enables us to evaluate the robustness of the detection procedures in question. On the other hand, a twofold increase of the number of active users can be interpreted as a result of jamming. In this case the intruder imitates the other users' activity by sending additional signals similar to those of the authorized users (this strategy is very simple and convenient for the intruder since it complicates still more the task of distinguishing between the signals sent by the intruder and those transmitted by the authorized users.) Thus if we use this interpretation we assume that the transmission power available to the intruder is 100 times greater than that available to the authorized user. In Fig.1 the dependences of value C_c (in bits per OFDM frame) for the second reception strategy on the value of the threshold coefficient are given. Values of C_c corresponding to the first strategy are also presented in Fig. 1. Points of the curves corresponding to the R_m values for the second strategy are indicated by the respective text marks (note that the values of C_c and R_m coincide for the first strategy.)

As is shown in Fig.1, in the second case threshold coefficient *k*=5 corresponds to the maximum value of C_c, which means that *k*=5 is this parameter's optimal value for the example under consideration. Note that a twofold increase of the number of active users results in the decrease of R_m by 0,07 bits per OFDM for both strategies. However, if the threshold coefficient is chosen in a proper way Strategy 2 is far more promising (since it ensures higher MPTR values). Therefore in what follows we shall consider only Strategy 2. In fact the performance degradation caused by the system load increase (either caused by the authorized users' activity or by multitone jamming) is moderate.

Now let us consider transponder jamming. Apparently the impact of the transponder jammer on the system performance depends on the signals' fraction the jammer is able to detect. Hereinafter a borderline case will be considered: we shall assume that the jammer can detect all the signals transmitted by all the authorized users. As the jammer detects a certain signal it sends a signal similar (i.e. having the same bandwidth and power) to the one used by the authorized user via the respective subchannel (note that it is practically impossible for the jammer to generate a signal antipodal to the one transmitted by the authorized user. Therefore in what follows we shall assume that the signal sent by the jammer has a random, uniformly distributed phase.) Thus, the jammer transmission power is more than 100 times higher than that of the authorized user. However the signals transmitted by the jammer are affected by attenuation just like those transmitted by the authorized users. The simulation results are presented in Fig. 2

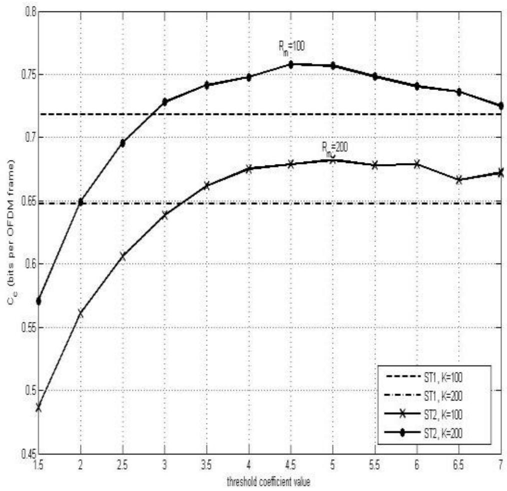

Fig. 1. Simulation results for the proposed strategies and various numbers of active users

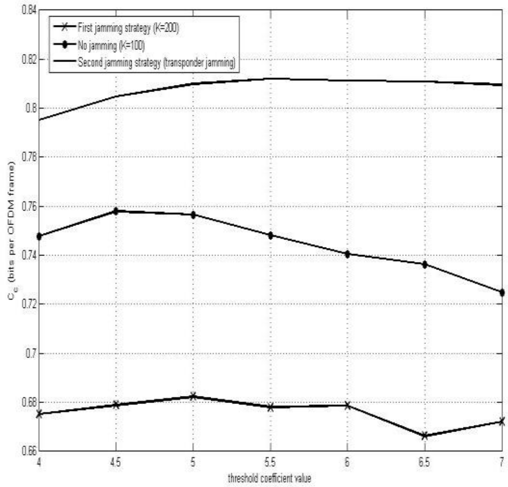

Fig. 2. Simulation results for various jamming strategies

As can be seen from Fig. 2, the maximum possible transmission rate of the active user increases if the signal is jammed by the transponder receiver. This result can be easily interpreted since the average power of the received signal grows if more than one user transmits in the same subchannel. Therefore we can conclude that the DHA FH OFDMA system using the proposed Strategy 2 is well protected from transponder jamming and can be considered most promising for implementation in real-life systems.

Conclusions

Hereinabove the problem of designing a detection technique that need not use CSI knowledge and power control and is well protected from both authorized and unauthorized users' activity has been considered. Simulation results show that reasonable choice of the threshold coefficient makes the resulting detector both jamming-proof and robust. Thus system models using this modified strategy can be considered promising candidates for possible implementation in real-life systems.

References

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