ADAPTATION OF THE MULTICARRIER COMMUNICATION SYSTEM USING BINARY PSO

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ABSTRACT

The multicarrier signaling is currently widely used in wireless communications and networking. The adaptation of transmitting parameters according to the actual environment and other requirements is desirable. This paper thus deals with the modified particle swarm optimization method used to adjust multicarrier communication system parameters (power and mapping on subcarriers) with respect to several optimization criteria. The particle swarm optimization adjusts the particles (agents) on the basis of information about the best previous particle's performance and the best previous performance of its neighbors. The work described in this paper introduces new criterion to achieve user defined data rate and allows switching-off of unnecessary subcarriers.

1. INTRODUCTION

The multicarrier signaling is currently widely used in wireless communications and networking. As the examples, the IEEE 802.11a/g or DVB-T/T2 use a principle of Orthogonal Frequency Division Multiplexing (OFDM).

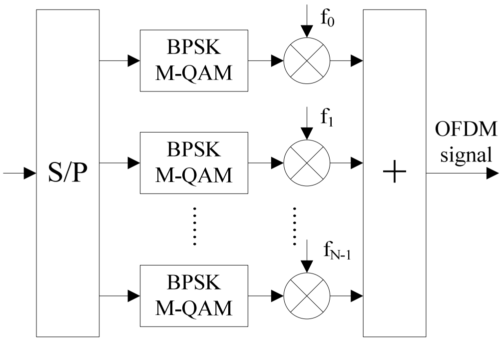

Fig. 1: Basic scheme of the multicarrier communication system (OFDM)

The adaptation of transmitting parameters according to the actual environment and other requirements is desirable. A technology of the multicarrier communication systems has possibility to change or adapt a few basic radio parameters. Examples of adjustable parameters are power of individual subcarriers, modulation type, bit (symbol) rate, etc. Settings of parameters have to correspond with actual channel situation. Figure 1 shows block scheme of Orthogonal Frequency Division Multiplex (OFDM) communication system with

N carriers. Serial data bits are converted into the *N* parallel branches. The stream in each branch is mapped according to the chosen modulation type (BPSK, QPSK, 16QAM and 64QAM). All branches are modulated on higher frequency and summed together. Output signal can be transmitted through the radio channel.

Particle swarm optimization (PSO) with special discrete form [1] has been chosen for adaptation of multicarrier system parameters. Optimization has been inspired by published paper [2]. In the presented paper a new criterion was used to keep constant data rate defined by the user. Moreover the system has a possibility to switch off any subcarrier, depending on the actual radio channel conditions and user needs. Ideas correspond with cognitive radio (CR) performance.

2. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization has been proposed as an optimization technique for the use in real number spaces [3]. A new potential solution is represented as a particle having position x_{id} and rate of change v_{id} in a D – dimensional space. Each particle i keeps a record of the position of its previous best performance in vector p_{id}. Adjusting of v_{id} in the direction of particle i according to the best previous position and the best previous position of any other particles in the neighborhood (p_{gd}). The actual velocity of the i-th particle is calculated by the following formula:

$$v_{id}^{t} = v_{id}^{t-1} + c_1 r_1 \left(p_{id}^{t-1} - x_{id}^{t-1} \right) + c_2 r_2 \left(p_{gd}^{t-1} - x_{id}^{t-1} \right), \tag{1}$$

where r_1 and r_2 are random positive numbers distributed in $\langle 0,1 \rangle$. Variables c_1 and c_2 denotes acceleration coefficients. Index d corresponds to the dimension of the solved problem and t represents actual iteration. New position of i-th particle is calculated according to the equation:

$$x_{id}^{t} = x_{id}^{t-1} + v_{id}^{t}. \tag{2}$$

Formula (2) is calculated each iteration step and for every particle.

2.1. PARAMETERS OF DISCRETE PSO

Often it is necessary to set up system parameters in discrete steps. Therefore a discrete binary version of PSO has been published in [1]. Two basic differences of continuous and discrete PSO are: the particles are represented as variables in binary form instead of the real number and velocity has been transformed into the change of probability. It means chance of the binary variable taking the value 1.

Position of i-th particle in iteration t denotes x_i^t. Whole position is described as $x_i^t = \left[x_{i1}^t, x_{i2}^t, \ldots, x_{iD}^t, \right]$, where D is the number of bits to represent a particle x_i^t. Number of bits used to encode position is determined by the range and the expected precision of the parameter. The velocity of the particle is still described in real number space and is calculated by the formula (1). Velocity of a particle is also determined by the previous velocity of the particle [1]. Sigmoid function $S(v_{id})$ [2] constrains velocity value into the interval $\langle 0,1 \rangle$:

$$S\left(v_{id}\right) = \frac{1}{1 + \exp\left(-v_{id}\right)}, \tag{3}$$

where $S\left(v_{id}\right)$ denotes the probability of bit x_{id} taking the value 1. If randomly generated number from interval $\langle 0,1\rangle$ is smaller then $S\left(v_{id}\right)$, then bit x_{id} become value 1, else x_{id} is zero. Swarm evolution is navigated by the best solution of particles which have the highest fitness value. Three objective functions have been used in the optimization. These functions are designed to minimize BER (4) [2], transmitting power (7) [2] and also reach the user defined data rate (8). The first objective function is:

$$f_{BER} = 1 - \frac{\log_{10}(0,5)}{\log_{10}\left(\overline{P}_{be}\right)}. \tag{4}$$

Variable $\overline{P}_{be}$ denotes the average BER over N subcarriers. In the considered communication system BPSK and M-QAM modulations on the subcarriers have been used. The bit error rate for BPSK is calculated using equation [4]:

$$P_e = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right), \tag{5}$$

where E_b denotes energy of bit and N_0 is a channel noise power spectral density. Bit error rate of M-QAM modulation can be expressed [4]:

$$P_e \approx \frac{1}{\log_2 M}\left(2\left(1-\frac{1}{\sqrt{M}}\right) erfc\left(\sqrt{\frac{E_b}{N_0}}\right)\right), \tag{6}$$

where M is a number of modulation states. The objective function to minimize transmitting power is defined as:

$$f_{power} = 1 - \frac{\overline{P}}{P_{\max}}, \tag{7}$$

where $\overline{P}$ is the average transmitting power of all N subcarriers. Variable P_{max} denotes maximum available transmitting power of the subcarrier. To achieve the constant data rate it is necessary to use third objective function:

$$f_{DATA} = 1 - \left|\frac{T^{-1}\sum_{n=1}^{N} \log_2 M_n - R_d}{R_d}\right|, \tag{8}$$

where T is duration of OFDM symbol and constant R_d is a desired and user defined data rate. Three objective functions are combined into the fitness function f:

$$f = w_1 f_{BER} + w_2 f_{power} + w_3 f_{DATA}, \tag{9}$$

where w_1, w_2 and w_3 are the weighting coefficients. Objective functions have been set up to approach value 1 in the optimal situation. Sum of the weighting coefficients give value 1.

In the simulations communication system with 32 subcarriers has been used. The power range of each subcarrier was chosen from 0 to 31 dBm with step size 0.5 dBm. The possibility to assign a zero power on any subcarrier was used. Six bits per one subcarrier is necessary to represent the transmitting power. The modulation types used in simulations were BPSK, QPSK, 16QAM and 64QAM. Two bits can represent the modulation type per one subcarrier for PSO algorithm. In this case it needs 256 bits to represent a potential solution. The searching space dimension was equal to 256.

3. SIMULATION RESULTS

The parameters of optimization were chosen according to the convergence of algorithm. Number of particles in the population was 50 and iterations finished after 500 runs. Acceleration coefficients were set as follow $c_1 = 0.2$ and $c_2 = 1$. Thus the algorithm prefers a global best value of fitness function. Duration of OFDM symbol was set to 4 μs. Maximum data rate in case of 64QAM modulation on all subcarriers is 48 Mb/s.

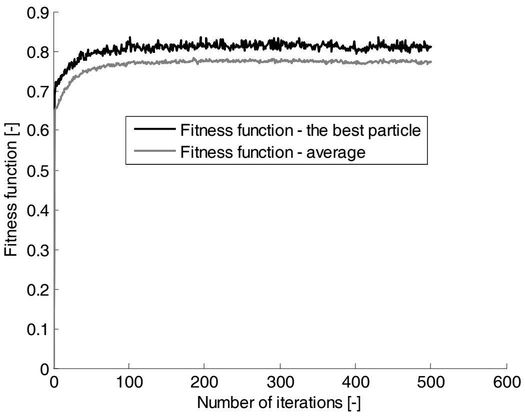

Fig. 2: Fitness function depending on the iteration number

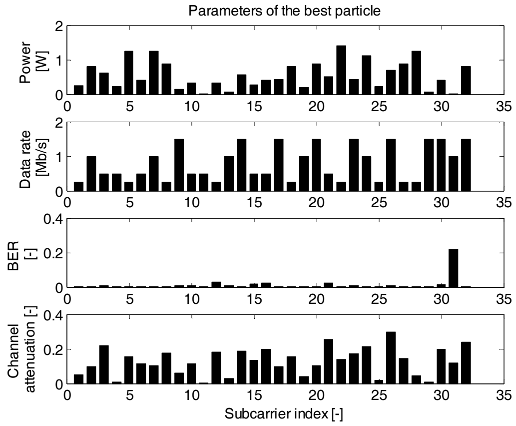

Fig. 3: Optimization results – minimization of bit error rate

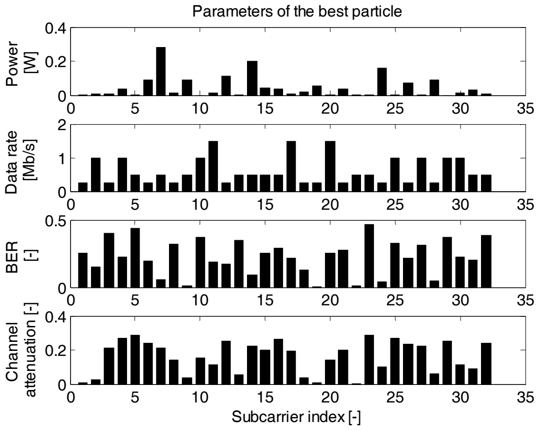

Fig. 4: Optimization results – minimization of transmitted power

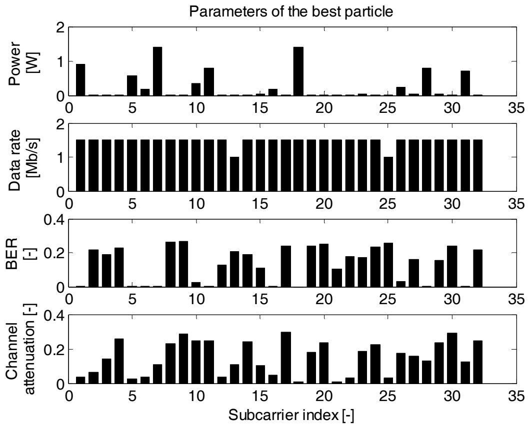

Fig. 5: Optimization results – hold on constant data rate 47 Mb/s

Fig. 2 shows the convergence of optimization. Note that all objective functions were set up to return value 1 in ideal case. Weighting coefficients were set up on the same value $w_{1\text{-}3} = 0.33$. User defined data rate was set up to 28 Mb/s. Fitness function approach value 0.9. Two curves are displayed in the graph. One of them corresponds to fitness function of the best particle, the second to the average fitness function over all particles. The optimized transmitted power, data rate and BER on the subcarriers are shown in the figures 3 to 5. The channel attenuation (inversely proportional to the channel noise power spectral density) represented by the random number in the interval $\langle 0;0.3\rangle$ is also included in the plots.

The first simulation was set up with weighting coefficients $w_1 = 0.8$, $w_2 = 0.1$ and $w_3 = 0.1$. Required data rate was chosen to 28 Mb/s. The aim of the optimization was minimized bit error rate. Fig. 3 confirms these results. Only bit error rate on subcarrier No. 31 was higher because of smaller transmitted power and higher channel attenuation. Data rate summed over all subcarriers was equal to 25.75 Mb/s (it corresponds to its smaller priority $w_3 = 0.1$).

Another simulation with different weighting coefficients ($w_1 = 0.1$, $w_2 = 0.8$ and $w_3 = 0.1$) minimized transmitting power all subcarriers. The desired data rate was set up to 28 Mb/s. Situation is shown in the Fig. 4. Note that the powers on the subcarriers No. 10 and 29 are equal to zero. Subcarriers are excluded from the transmission and the spectrum becomes non-continuous. The unused frequency space can be potentially used by the other narrow band user. It is the expected result, because of higher channel attenuation on subcarriers frequencies. The most of subcarriers use the constellation mapping with the lower number of states (as a consequences of lower data rate).

Weighting coefficients are set up to prefer an achievement of defined data rate. The maximum value (48Mb/s) was required. The best result of optimization returns data rate of 47 Mb/s. It corresponds to 64QAM modulation over all subcarriers excluding two subcarriers. Bit error rate was relatively higher depending on the actual channel attenuation.

4. CONCLUSION

In this paper the modified binary particle swarm optimization used for adjusting parameters of multicarrier communication system was described. The main optimized parameters were the bit error rate, the transmitted power and the data rate. The obtained results show the ability of the communication system to achieve and hold on the user defined data rate. The results also show the possibility to assign zero power to unused subcarriers. Free subcarriers can be used by other user or it can reduce the frequency bandwidth. Described multicarrier communication system can be used in cognitive radio applications.

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