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Performance Comparison of Power Control Methods That Use Neural Network and Fuzzy Inference System in CDMA

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ABSTRACT

In the cellular communication applications of Code Division Multiple Access (CDMA) system, each user signal can be received in the different power levels in the input of the base station due to different distances of the users. In that case, signal of the user that is closer to the base station increases the communication errors of the far users. To solve this problem, open or closed loop power control system is used to make each user signal equals in the input of the base station. Power prediction and power control have been performed with various methods in the literature. In this study, two different methods will be investigated and will be compared with each other in terms of power control performance. The power at the output of the matched filter is predicted using neural network and fuzzy inference system, power control is realized according to the predicted values.

Keywords*—CDMA; Power Control; Neural Network; Fuzzy Inference System*

I. INTRODUCTION

In a code division multiple access (CDMA) system, a number of users simultaneously transmit information over a common channel, each user`s signal is assigned a different signature waveform, and the received signal is the superposition of the signals transmitted by each user. In the receiver, user data is obtained by multiplying the received signal with its own spreading code. In the system, when the signal powers of the users are different, errors of the user data that has weak signal power increase; this situation is called as the near-far problem. The power controlsystem is used to overcome this problem. The power control system assures that all signal levels are the same in the input stage of the base station.

The power control is performed as open-loop or closed-loop. In the open-loop control, the power of the mobile user`s transmitter is adjusted by itself evaluating signal power that is transmitted from the base station. In this method, path losses are assumed as the same from the base station to mobile user and from the mobile user to the base station. However, open-loop control is not sufficient method, because these losses can not be the same in the real application. In the closed-loop control, base station detects the power level of the mobile user and transmits power control signal to the mobile user to adjust its power. In this way, all the mobile user`s signals are received in the base station with the same power level due to control signals that is transmitted from the base station system. However, determination of the signal power of each mobile user in the base station is not easy process, because all the user`s signals are combined as one CDMA signal. There are various studies about this subject in the literature, but generally they consist of complex structures. A FIR filter was used for prediction of the signal power in [1]. A predictive low pass filtering was used to improve power estimation in [2,3,4]. A fuzzy system was used to make power level estimation in [5]. However, an optimized neural network was used for power prediction in [6], and Elman neural network were used to control the power in [7] with the complex structures. Neural Network was used to predict the power from output of the matched filter in [9] and Fuzzy Inference System was used to predict the power from output of the matched filter in [10].

In this study, Neural Network (NN) and Fuzzy Inference System (FIS) will be compared in terms of power control performance in CDMA system. The power level prediction is realized with NN and FIS by evaluating outputs of the matched filters, and the closed-loop power control was used to adjust the power of the mobile user by small steps.

II. SYSTEM MODEL

We consider synchronous CDMA system with binary phase shift keying (BPSK) modulation in an additive white Gaussian noise (AWGN) channel. Data for each user as random series in form of -1,+1 is generated and multiplied with its spreading code to obtain a CDMA signal. The CDMA signals of all users and AWGN are added in the channel. At the receiver, the received CDMA signal with the K users is multiplied with kth user signature waveform and integrated in one bit period to make an estimation for kth user bit. The output of the kth matched filter in one symbol interval yk is given by

$$y_k = A_k b_k + \sum_{\substack{j=1 \\ j \neq k}}^{K} A_j b_j \rho_{jk} + n_k \qquad (1)$$

where bk is the input bit of the kth user (desired user), bk∈{-1, +1}, bj is the input bit of the jth user, Ak is the received amplitude of the kth user, Aj is the received amplitude of the jth user, ρ_{jk} is the cross-correlation coefficient between desired user and the jth user, and nk is additive white Gaussian noise. The second term in Eq.(1) is the multiple access interference (MAI) that is effect of the other active users. In the base station, the power level of each user is determined with the output of the matched filter as:

$$p_k = \frac{1}{M} \sum_{j=1}^{M} (y_{k(j)})^2 \qquad (2)$$

Where pk is the power of the kth user, k is the user`s number and M is the number of the bits that are considered in the calculation of the power. The power estimation and the control are done with the outputs of the matched filters as in Fig. 1.

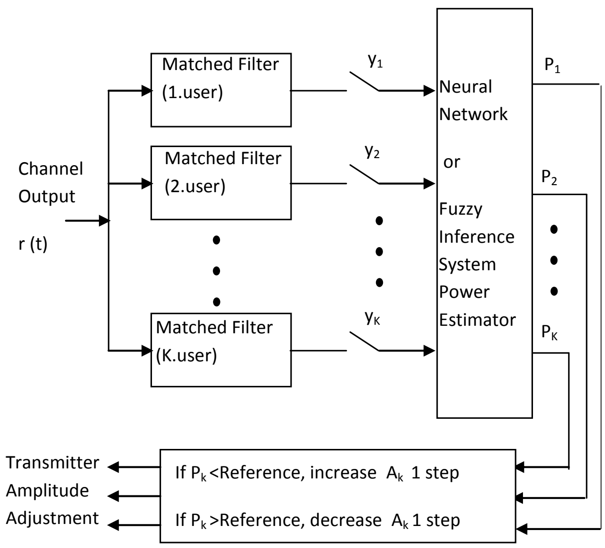
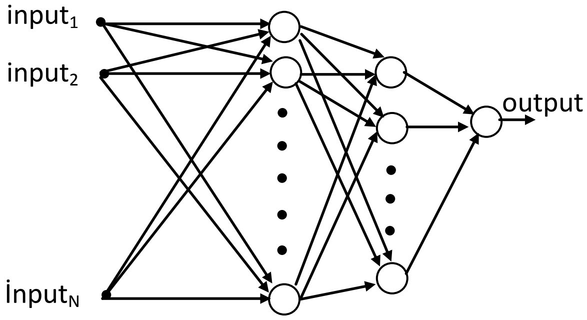


Fig. 1. The structure for the power estimation from the outputs of the matched filters and the control of the power level.

III. ARTIFICIAL NEURAL NETWORKS

The neural networks are constructed with neurons that connected to each other. Each connection has a weight factor and these weights are adjusted in a training process. There are many types of the neural networks for various applications in the literature. A common used one of these is the multilayered perceptrons (MLP) [8]. MLPs consist of input, hidden and output layers and they have feedforward connections between neurons. Neurons in the input layer only act as buffers for distributing the input signals to the neurons in the hidden layer. There are various activation functions that are used in the neurons. The weights are changed with various learning algorithm for getting proper output. The basic structure of the neural network with N input and one output is shown in Fig. 2. In this study, the Levenberg-Marquardt algorithm is used as the learning algorithm for the MLPs [8].



The basic structure of the neural network with N input, one output.

IV. FUZZY INFERENCE SYSTEM

Fuzzy Inference System (FIS) constitute the outputs by evaluating the inputsaccording to the rules defined before.The structure of Fuzzy Inference System with r rules, n inputs and m outputs is shown in Fig. 2. Fuzzy inference process is made of 5 parts. Adjustment of the inputs variables to the fuzzy values, application of the fuzzy logic operands (AND or OR) to the adjusted values, obtaining the end values from the initial values, evaluating of the obtained values according to the rules, and back transformation from the fuzzy logic values.

In this study, Sugeno type FIS is used after the matched filter, the character of proper membership function for FIS is determined by calculating the power of an user in equation 2. In this receiver; Gaussian has been used for all of the input membership functions, triangle type has been used for output membership functions, and VE operator has been used between the inputs. Rules are set as depended on the power values which are calculated from equation 2 different power level matched filter output, and are depended on the number of user. For 3 users, 16 rules are being applied and for this reason 16 bit training data is sufficient. Output power for every user is determined according to these 16 rules. These rules can be determined for 2 different power levels like this:

$$\text{Rule(j): IF } y_{1j} \text{ and } y_{2j} \text{ and } \ldots\ldots\ldots y_{Kj} \text{ THENoutput}_k = P_i$$

where k=1,2,…,K (K number of users), j=1,2,…,J (J number of bit $J=2x2^K$), i=1 and 2, P consists of output power and different power levels used in training for user.

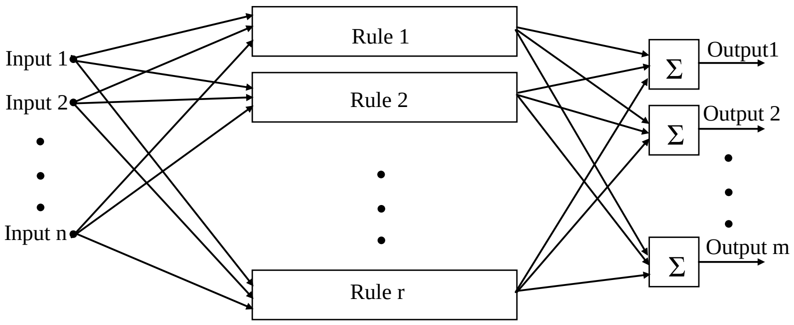


Fig. 2. The structure of Fuzzy Inference System with n inputs, r rules and m outputs.

V. SIMILATION RESULTS

In the simulation of the CDMA system, 31 bits length spreading codes that have normalized cross-correlation 0.2258 between each other were used. Cross-correlation value is selected bigger to create a more severe near-far environment. The simulations were done in the three users synchronous AWGN channel.

In the neural network that is used in the system, the number of the input and hidden layer nodes were chosen as the number of the users, and the number of output node was chosen as 1. The network is a feed forward network and it was trained by Levenberg-Marquardt algorithm. In the hidden layer tangent sigmoid activation function was used and in the output layer pure linear activation function was used. The power estimation and the control were done only for the first user that is selected as the desired user. The power control was performed to make the powers of the all users as 2 watt in the input of the base station. The powers of the second and the third users were assumed as 2 watt during the training and in the simulations. The training data that is produced for the three different power level as 1,2 and 3 watt were used during the training. The 8 bits training data that is all the possible combinations of three users were used without noise for each power level.

In the simulation, the performance of the power estimation and control of the neural network and fuzzy inference system was examined in the synchronous AWGN channel with 10 dB and 25 dB signal to noise ratios (SNR) of the first user. The SNR of the first user is defined as:

$$SNR_1 = \frac{signal\ power}{noise\ power} = \frac{A_1^2}{2\sigma^2} \tag{3}$$

where $\sigma 2$ is the variance of the Gaussian noise with the zero mean value, A1 is the amplitude of the first user`s signal and Ak is the amplitude of user k's signal. All the simulations were done for the three methods as mean of the squares of the output of the matched filter of the first user, the neural network and fuzzy inference system estimator. The powers of the second and the third user were assumed as 2 watt whereas the power of the first user was assumed as 1 watt at the beginning. The power control was performed to make the power of the first user 2 watt in the input of the base station. The amplitude of the first user was changed by the 0.1 steps depending on estimated power level. The results for the case that is considered 1 bit and 50 bits for each estimation are shown in Fig. 4 and Fig. 5, respectively, for 100 different estimation in the channel with 10 dB SNR value. As it is shown, the estimation performance of the neural network is better than mean squares method, and also fuzzy inference system is much better than neural network. Power control can be done between 0 watt-5 watt with mean squares, 1.5 watt-3 watt with neural network and 1.8 watt-2.8 watt with fuzzy inference system by considering 1 data bit for each estimation in the channel with 10 SNR value.Furthermore, in the case that is considered 50 bits for each estimation, power control performance gets better for all methods. Fuzzy inference system has still the best performance. A better estimation can be done by considering more values for the estimation, but in that case estimation time increases.

Furthermore, the case that is considered 50 bits for each estimationin the channel with 25 dB SNR value is shown in Fig. 6.As it is shown, the power control depends on neural network and fuzzy inference system estimator can be performed very good especially for the bigger SNR values.Fuzzy inference system has the best performance again.

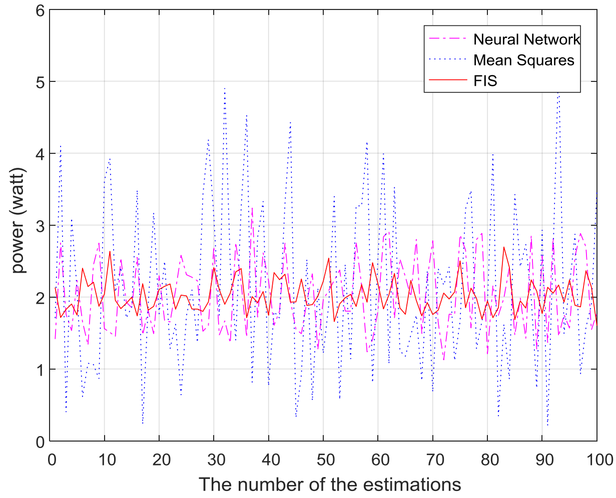


Fig. 3. The power control performance considering 1 bit data foreach estimation in the channel with 10 dB SNR value.

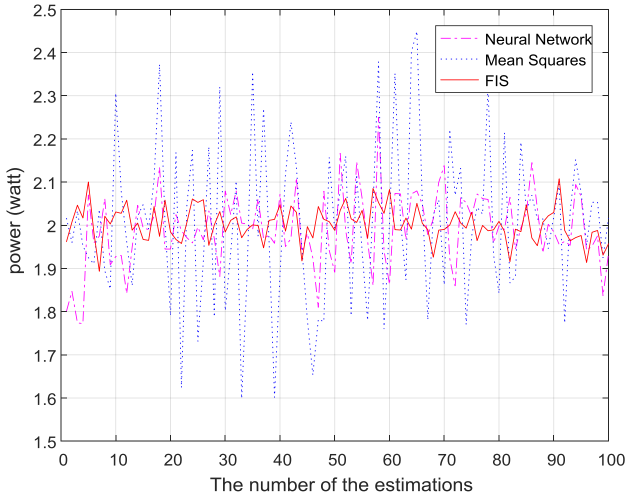


Fig. 4. The power control performance considering 50 bit data foreach estimation in the channel with 10 dB SNR value.

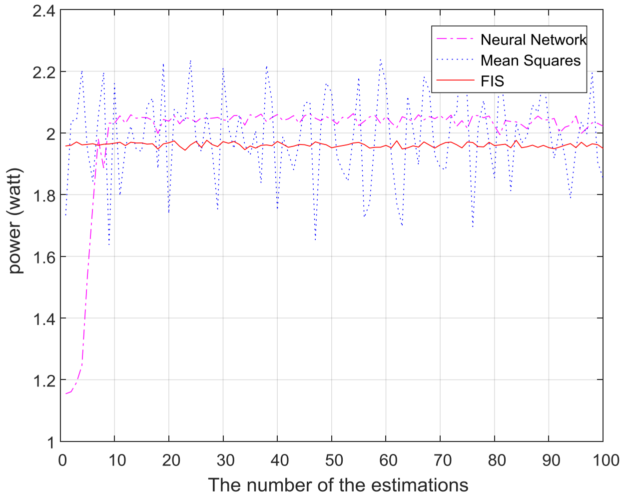


Fig. 5. The power control performance considering 50 bit data foreach estimation in the channel with 25 dB SNR value.

VI. Conclusion

The power level can be defined by calculating mean-squares of the values that are taken from the output of the matched filter. However, the number of the considered values for the calculation of the power level must be high to get more correct power level. But considering more values causes slow power control. The power control must be fast enough for the effective communication. Simulations results show that the fast power control can be performed with NN and FIS approach even in 1 bit period. However, the estimation performance of the Fuzzy Inference System is better than Neural Network. Performances of the NN and FIS estimators get better for the bigger SNR values. A better power estimation can be done by considering more values for the estimation, but in that case estimation time increases.

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