Genetic Algorithms for Multiuser Detection in Synchronous CDMA

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Abstract — **The optimal multiuser detector for communication systems can be characterized as an NP-hard optimization problem. In this paper, application of genetic algorithms to suboptimal multiuser detection is studied. The performance of the genetic algorithm multiuser detection is studied by computer simulations. They demonstrate that a good initial guess vector is needed to obtain a superior performance. If the decorrelating detector output is included in the set of intial guess vectors, the performance of the genetic algorithm detection is close to that of the single user system.**

I. Introduction

The optimal multiuser detector [1] for communication systems can be characterized as an NP-hard (non-deterministic polynomial) optimization problem, complexity of which increases exponentially as function of number of users. Due to high complexity of the optimal multiuser detector, several suboptimal detectors have been proposed [2].

There are several ways to approximate solutions to NP-complete optimization problems. They include genetic algorithms, which have given good results on some travelling salesman problems [3]. In this paper, we study the application of genetic algorithms to multiuser detection.

II. Genetic Algorithms

Genetic Algorithms model the natural selection and survival of the fittest [3]. The genetic algorithms solve optimization problems iteratively. On each iteration (generation) they use a set (a population) of possible bit vectors (strings), from which a new set of bit vectors is generated. First, the selection process copies individual bit vectors according to their fitness values, which is measured by the log-likelihood function in the multiuser detection. The selected bit vectors are mated randomly and they generate the new generation of individual bit vectors by crossover: an integer position k along the bit vector is selected uniformly between 1 and the bit vector length $K-1$; two new bit vectors are created by concatenating the first k bits of one vector with the $K-k$ bits of the other vector. In addition to the above operations, a random change of a single bit from -1 to 1 or vice versa, called mutation, is also used in genetic algorithms. The mutation operator is needed, since reproduction and crossover may loose some potentially useful information. [3]

III. Genetic Algorithms for Multiuser Detection

Genetic algorithms can be rather straigthforwardly applied in multiuser detection. However, some modifications have to be made. The function that a genetic algorithm attempts to maximize must always be positive. Therefore, the log-likelihood function has to be monotonically mapped to a positive function. Two mappings, namely an exponential (resulting in likelihood function) and offset mapping, were compared. The exponential mapping was observed to give better results.

The performance of the genetic algorithm multiuser detectors is very difficult, if not impossible, to analyze. Therefore, Monte-Carlo computer simulations were performed to study the performance of the genetic detectors. Random spreading sequences with length 31 were used. The number of user was $K = 20$. The interfering users were assumed to have 3 dB higher power than the desired one. Three kinds of intial guess sets were used:

1. a set containing random intial guess vectors only,
2. a set containing the decisions of conventional matched filter detector and random initial guess vectors,
3. a set containing the decisions of the decorrelating detector, the decisions of the conventional matched filter detector, and random initial guess vectors.

The results show that the genetic algorithms can improve the initial guesses. However, at high signal-to-noise ratios with bad initial guesses the bit error rates saturate, and the genetetic detectors are outperformed by the decorrelating detector. With good intial guess set, i.e., if the decorrelating detector output is included, there is no saturation effect, but the single-user system performance is approached. In other words, the genetic algorithms can provide neither robust multiuser detection performance nor near-far resistance. However, when combined with some suboptimal detector the genetic algorithms have the ability to further improve the detection performance.

IV. Conclusions

The application of genetic algorithms to multiuser detection was studied. The computer simulations demonstrated that a good initial guess vector is needed to obtain a superior performance. If the decorrelating detector output is included in the set of intial guess vectors, the performance of the genetic algorithms is close to that of the single user system.

References

[1] S. Verdu, "Minimum probability of error for asynchronous Gaussian multiple-access channels," *IEEE Trans. Inform. Th.*, vol. 32, no. 1, pp. 85–96, Jan. 1986.

[2] S. Verdu, "Multiuser detection," in *Advances in Statistical Signal Processing*, vol. 2, pp. 369–409. JAI Press Inc., Greenwich, CT, 1993.

[3] D. E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addison-Wesley, Reading, MA, 1989.

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