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Modified genetic algorithm based power allocation scheme for amplify-and-forward cooperative relay network☆

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ABSTRACT

Cooperative relay (CR) is a favorable technique to provide better spectral efficiency and enhance the cell coverage area in a cost-effective manner. However, several undesired issues, such as high-power consumption, arise due to use of a high number of relay nodes (RNs) in the network, Moreover, in a dynamic environment, full channel state information (CSI) is not always available. Therefore, all RNs need to calculate the abrupt changes in the channel; otherwise, the overhead delay will increase and the RNs will consume higher network power. To address this, an optimized modified genetic algorithm (Modified GA) based scheme is proposed that utilizes probabilistic selection rules and fitness scores. The results are presented in terms of symbol error rate (SER), network capacity, power consumption, and power improvement in order to analyze the performance of the proposed scheme. The results show that the proposed scheme provides better overall performance as compared to conventional optimization approaches.

1. Introduction

Modern techniques in the area of networking and wireless communication have been the subject of research focus in the past decade. With the number of mobile users expected to increase considerably in the near future, the demand for high data rates and higher capacity with larger coverage areas will also increase [1]. Wide area networks can provide larger cell coverage up to 20 km. However, subscribers can face low signal quality due to various types of issues, such as fading, scattering, path loss, and interference. These issues not only affect the throughput but also degrade the overall network performance. Quality of service (QoS) is one of the most important criteria in base station (BS) to user equipment (UE) communication, in which the required signal cannot be perceived properly since the strength of the received signal is very low [2]. A simple and optimal approach to mitigate this issue is to transfer several copies of the desired signal, by making use of spatial, time, frequency, code, or hybrid diversity. The formation of a distributed network is highly supported by cooperative communication, which allows ingenious collaboration of communication resources. This is done by allowing terminals or nodes in a communication network to pool resources with each other in the transmission of information [3]. Higher coverage area, better spectrum diversity, and optimum throughput can be achieved by deploying many relay networks in a cooperative relay (CR) network, in which more user throughput can be achieved by using a better modulation and

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coding scheme (MCS) [4].

Relay nodes (RNs) are used to enhance the signal strength by collecting information from the BS and transferring it to the UE without any significant information loss. In conventional CR systems, RNs are operated either in the half-duplex (HD) or full-duplex (FD) mode. In the HD mode, the BS-RN-UE link operates either in frequency-division duplex (FDD) or time-division duplex (TDD), whereas in the full-duplex (FD) mode, it shares a common time-frequency signal-spectrum for reception and transmission [4]. Relaying techniques are generally categorized into two different relaying protocols, namely amplify-and-forward (AF) protocol and decode-and-forward (DF) protocol. In AF protocol, the signal received from the BS is amplified by the RNs, and then, the amplified signal is forwarded to the desired destination. In DF protocol, the RNs decode the signal received from the BS, and then, a regenerated copy of the same signal is transmitted to the desired UE [4]. Several QoS parameters can be utilized to investigate the performance of a CR network, such as power consumption, power improvement, network capacity, and SER. In the CR network, power consumption gradually increases due to the addition of RNs with the BS. This issue can be mitigated by using various power allocation (PA) schemes, including equal PA, particle swarm optimization (PSO), artificial bee colony (ABeeC) algorithmic, and GA-based optimization scheme [5]. Moreover, the SER performance of the AF and DF protocols are correlated, although the AF protocol maintains a lower complexity, and therefore, only the AF protocol is considered in our contribution [6]. In order to control the error reduction and the enhancement of the spectral efficiency in the AF CR network, the most effective technique used is the PA of the RNs. The optimum performance for HD RNs can be achieved by using the two-dimensional PA optimization technique, which involves location optimization and energy optimization. Owing to the unavailability of full CSI, the current PA optimization schemes cannot be used [7]. Moreover, the distribution of the signal to interference plus noise ratio (SINR) and corresponding power and location optimization for the FD RNs are different from the conservative HD network, and therefore, some advanced less complex optimization schemes are needed. Owing to a high number of RNs connected to the network, the amount of power consumption gradually increases, especially while working on the AF mode of the CR network. This issue can be rectified by using a better PA scheme, which not only decreases the system delay but also optimizes the power consumption [8].

In order to resolve the discussed issues, a modified GA-based optimization scheme is proposed in this paper for the AF mode of CR networks. The proposed algorithm differs from conventional search and optimization methods in three signification points. 1) It performs a parallel search from the population of points, and therefore, it has the ability to avoid being trapped in a local optimal solution as in the case of conventional methods. 2) It works on the chromosomes, which are an encoded version of the potential solutions parameters, rather than optimizing the parameters themselves. 3) It utilizes fitness scores, which is obtained from the objective functions without any other artificial black-box mathematics. The optimal solution has been detected by the users, which typically chooses the best structure of the last population as the final solution. The main contributions of this paper are summarized as follows:

1. This paper proposes a fine-tuned hybrid modified GA to set utility functions. This optimization technique is highly effective, which imitates the phases of mutation and crossover in the evolution of a chromosome to effectively find the optimal solution.
2. To simplify the analysis, the solutions are considered as chromosomes and ‘good’ or ‘bad’ chromosomes are evaluated, depending on the fitness function. Therefore, new solution sets are created by using the recombination of ‘good’ chromosomes only.
3. Utilization of elitism helps to avoid the possibility of losing the best chromosomes that are available in the generation. It also formulated two constraints, namely bound and linear, which helps to reduce the SER of the network capacity with minimal power consumption.

The details of proposed modified GA approach will be discussed in Section III. The results will be assessed for SER, capacity, power consumption, and power improvement with respect to the signal-to-noise ratio (SNR) and for different number of RNs in the network. The proposed work outperforms the equal PA, PSO, and ABeeC schemes, which is reflected in this empirical study. The rest of the paper is organized as follows: in Section II, the related work present in the literature is discussed. The evaluation of the system model for the CR network and the identification of the weight optimization problem is discussed in Section III. Furthermore, Section IV explains the proposed modified GA technique. Subsequently, all numerical results and discussion are described in Sections V (A) and V (B). Finally, the conclusion and future work are presented in Section VI.

2. Related work

In CR communication networks, the PA of each node is a critical issue determining system performance, especially in power-constrained CR networks. Suitable PA among BS and RNs can drastically lower the power consumption and extend the lifespan of the network. Therefore, most recent research has focused on minimizing the power consumption, increasing the transmission rate, enhancing the diversity gain, and reducing the SER, in the field of cooperative communication. This paper proposes a GA-based approach for reducing the power consumption of the CR network. The GA approach is selected owing to its ability to utilize both mutation and crossover phases, which makes it more immune to be converged as a local optimal solution by making its population more diverse. This diversity helps the algorithm quickly reach the global optimal solution since it enables faster exploration of the solution space by the algorithm [9]. Further, GA's selection rule is probabilistic rather than deterministic. It works on the chromosome (encrypted form of potential parameters of the solution), rather than the parameters themselves. Moreover, GA uses the fitness score (FS), which derives from impartial functions, without other supplementary information or derivative. Furthermore, GA-based algorithms can achieve superior performance for the unknown environment and asymmetric channels. A few related research works are discussed as follows.