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Finding a robust configuration for the AEDB information dissemination protocol for mobile ad hoc networks☆

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ABSTRACT

The Adaptive Enhanced Distance Based Broadcasting Protocol, AEDB hereinafter, is an advanced adaptive protocol for information dissemination in mobile ad hoc networks (MANETs). It is based on the Distance Based broadcasting protocol, and it acts differently according to local information to minimize the energy and network use, while maximizing the coverage of the broadcasting process. As most of the existing communication protocols, AEDB relies on different thresholds for adapting its behavior to the environment. We propose in this work to look for configurations that induce a stable performance of the protocol in different networks by automatically fine tuning these thresholds thanks to the use of cooperative coevolutionary multi-objective evolutionary algorithms. Finding robust solutions for this problem is important because MANETs have a highly unpredictable and dynamic topology, features that have a strong influence on the performance of the protocol. Consequently, robust solutions that show a good performance under any circumstances are required. In this work, we define different fitness functions that measure robustness of solutions for better guiding the algorithm towards more robust solutions. They are: *median*, *constrained*, *worst coverage*, and *worst hypervolume*. Results show, that the two worst-case approaches perform better, not only in case of robustness but also in terms of accuracy of the reported AEDB configurations on a large set of networks.

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1. Introduction

MANETs or mobile ad hoc networks, are spontaneously created between neighboring devices with communication capabilities. They do not use nor rely on any existing infrastructure that manages the appearance and disappearance of devices, the location (due to the mobility) or selfish behaviors that detriment the network performance. Communication is challenging due to variability of the channel, physical obstacles, collisions in the shared medium, or any other physical phenomena that might affect communications (e.g., the Doppler effect or fading). For that, the topology of MANETs is highly dynamic and unpredictable.

Due to all these specific characteristics of MANETs, communication protocols must be reformulated and cannot be reused from other networks. Considering the intrinsic broadcast nature of the wireless medium and that broadcasting is a cornerstone in networking, in this paper we focus on dissemination protocols. Broadcasting is generally associated with the broadcast storm problem [51], but due to all the intrinsic challenges and characteristics of MANETs, the main problem in broadcasting is not only reducing the number of forwardings, but also trying to overcome all these undesirable aspects.

All the mentioned specific features, make difficult the design of communication protocols tailored for MANETs. In order to adapt to the unpredictable topology, most of the protocols rely on a set of parameters that automatically change the protocol behavior according to the current situation. Protocols are usually highly sensitive to both small changes in the set of configuration parameters and the network where it is tested on. One example is the AEDB communication protocol [56], the subject of study in this work. It is an energy-aware broadcasting protocol that uses a cross-layer

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design to reduce the energy consumption. It adapts to topology changes thanks to a set of different parameters. In our previous work [21], we tackled the problem of fine tuning AEDB parameters to optimize three different goals, in conflict with each other: the coverage of the broadcasting process, the overall energy consumption, and the network use. We have tackled the problem with a number of different algorithms in the past [21,43]. In order to find confident results, solutions were evaluated on 10 different networks in our previous work, and their fitness values were assigned according to the average performance in all the networks. The solutions provided by the algorithms resulted overspecialized, because further experiments showed a deterioration on the performance on a large number of unseen tested networks. Therefore, additional methods need to be designed in order to find robust solutions. Here a robust configuration means that it offers a more stable performance on a large number of networks.

In [22], we proposed two parallel cooperative coevolutionary multi-objective versions of NSGA-II that offered super-linear speed-ups and found more robust configurations of the protocol, compared to the original NSGA-II. The NSGA-II algorithm was chosen after the highly competitive performance it showed against the previously mentioned ones. The current paper is an extension of that work. Here, we further investigate on the generation of robust configurations of AEDB, using the best performing algorithm in [22].

The contributions of this paper are detailed next. First, we propose four new definitions of the problem to guide the algorithm towards more robust solutions. Second, we solve them with the CCNSGAII algorithm and select the best five solutions obtained for every problem definition, and we extensively evaluate their performance on 1000 networks. Third, we compare five different robust optimization approaches (the four proposed methods, plus the previously existing one for this problem), on this highly dynamic problem and on a large number of networks, paying special attention to the stability of the performance of the solutions in all tested networks. Our conclusions are supported by a 95% statistical confidence.

The paper is organized as follows. We revise in the next section the most relevant works in the literature on protocols optimization for MANETs. Section 3 describes the AEDB protocol, the optimization problem tackled in our previous work, and justifies the need for robust solutions. The proposed methods to find robust solutions to the problem are presented in Section 4, and the cooperative coevolutionary optimization method we use is introduced in Section 5. The experimental analysis and results are reported in Sections 6 and 7, just before formulating the conclusions and main lines for future work in Section 8.

2. Related work

In this section, we briefly describe some of the most relevant works available in the literature. We first focus in Section 2.1 on the application of evolutionary algorithms in the context of ad hoc networks, and then we discuss in Section 2.2 about the main existing robust multi-objective optimization approaches in the literature.

2.1. Evolutionary algorithms for broadcasting optimization in mobile ad hoc networks

Nature inspired algorithms have been widely used for a vast number of real world applications [52,61]. Among them, *simulation optimization* problems (i.e., those that integrate optimization techniques into simulation analysis), as the one studied in this paper, have been successfully applied in different domains [5,66].

There are a large number of simulation optimization problems defined in the context of MANETs, but only a reduce number of them deal with broadcasting or related problems. We emphasize in this section a number of relevant works, but for a complete and detailed survey on the topic the reader is referred to [21]. We can classify them as online or offline [21], depending whether the optimization algorithm is executed in the network nodes or not, respectively.

In online techniques, algorithms must be computationally light, and can only make use of local knowledge to take decisions. Therefore, it is a difficult scenario for the application of evolutionary algorithms. There are only a few approaches based on Particle Swarm Optimization [42] and Genetic Algorithms (GAs) [12] for efficient multicasting in MANETs, but they usually require high computational resources in the nodes composing the network, and they are therefore not appropriate for most kinds of MANETs. We could not find any work dealing with online evolutionary algorithms for broadcasting.

Offline techniques are the subject of study in this paper. We can identify two different kinds. One of them consists on the application of the optimization algorithm in a centralized entity with global knowledge of the network that takes decisions online according to the state of the network at a given time. The other is the use of the optimizers in the design process of the network and protocols used, so no optimization is done during the life of the network. We are interested in this paper in the second case. The first case is difficult to implement in practice, because the centralized entity must have precise knowledge of the global status of the network. Additionally, the presence of such a centralized entity is against the nature of MANETs. However, these approaches can be used to find near-optimal solutions that can be used to validate the quality of simpler decentralized protocols [63]. We found one paper that requires the use of a centralized entity to solve the multicasting [10] using evolutionary algorithms. The proposed immigrants based GA can quickly adapt to the the network topology changes and produce high quality solutions following each change, differentiating it from other similar approaches that can only be applied to static networks.

We focus in this paper on the use of optimization algorithms for the fine-tune of a broadcasting protocol. The first study in this line, was probably the one by Alba et al. [4], in which a broadcasting protocol for MANETs was optimized in terms of different objectives using a multi-objective genetic algorithm. After this initial paper, a number of works appeared studying the same problem in the literature [23,29]. The minimum energy broadcast (MEB) problem is a well known problem in wireless ad hoc networks [9], and different metaheuristics have been applied to solve it. It has been tackled, for example, with Particle Swarm Optimization [41], evolutionary algorithms [76], ant colony optimization [38,39], Evolutionary Local Search [75], Iterated Local Search [45], or hybrid GAs [67]. All these techniques require the global knowledge of the network, so their applicability in real scenarios is limited.

In vehicular ad hoc networks we can find that Abdou et al. [2] optimized a probabilistic broadcast protocol to send an emergency message in terms of the local network density. The multiobjective optimization focuses on minimizing the channel utilization as well as the broadcasting time.

Ruiz et al. [57] optimize the performance of AEDB using two well known multiobjective algorithms (CellDE and NSGA-II), by maximizing the coverage achieved in the dissemination process and minimizing both the time and the energy used. The authors study later in [22] the performance of two cooperative coevolutionary multi-objective genetic algorithms (CCMOEAs), compared to NSGA-II, finding that even when the CCMOEAs found less accurate results, the performance of the configurations they found showed to be more stable in a further study on 100 networks, compared to the solutions of NSGA-II.

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