A Survey of Ant Colony Optimization Algorithms for Telecommunication Networks

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ABSTRACT

Optical and ad-hoc networks which fulfill the communications requirements of complex applications must meet the Quality of Service (QoS) demanded by these applications, such as transmission delay. These demands are hard to satisfy in the presence of unpredictable behavior in the environment such as interference, traffic congestion, etc. Algorithms based on Ant Colony Optimization (ACO) offer an effective approach to meet such challenges since they are well suited to the dynamic routing optimization and dynamic resource reassignment required by these applications. In this paper, the author presents a survey of Ant Colony Optimization variants applied to ad-hoc and optical networks. The ACO variant called AntHocNet in particular will be reviewed, analyzed, and criticized from the point of view of emergent applications for environment management such as Intelligent Transportation Systems (ITS).

Keywords: Ad-hoc Networks, Ant Colony Optimization (ACO), AntHocNet, Intelligent Transportation Systems (ITS), Routing Protocols, Vehicular Ad-hoc Networks (VANETS)

1. INTRODUCTION

Performance degradation is a constant threat for the telecommunication networks that support Intelligent Transportation Systems (ITS). Interference caused by signal noise and by obstacles in the man-made or natural environment affecting the physical layer of these networks is the main source of performance degradation. To minimize such interference, communication protocol designers rely on metaheuristics to maintain the algorithms that are routinely used to achieve optimal paths for both vehicle and packet routing in ITS telecommunication networks.

The problem of finding the optimal path in a given network is a combinatorial one whose solution requires heuristics, especially since the vast search-space of candidate solutions excludes an exhaustive search based on exact processing. However, given the countless variables related to the shortest path search for ITS applications, finding a solution by heuristics is simply not feasible. Not surprisingly, metaheuristic methods have proven to be more suitable than simple heuristics since they are generic and are not only designed to solve different categories of problems but also can solve complex problems.
Important research contributions have been made on metaheuristics based on different techniques such as simulated annealing, genetic algorithms, Ant Colony Optimization (ACO) algorithms and tabu search (Dréo, Pétrowski, Siarry, & Taillard, 2003). A number of studies have attempted to compare selected metaheuristics, such as ACO and genetic algorithms, in terms of their success in solving the same problem. Performance comparisons are not meaningless due to the instantiations of metaheuristics parameters, but comparisons based on their use in different application domains are more significant since the behavior and operation of a metaheuristic are often mapped naturally to the operations of specific applications.

In this paper, we survey different alternatives of the ACO algorithms applied especially in the context of telecommunication networks such as ad-hoc and optical networks. In Hartenstein and Laberteaux (2010) many technologies are considered for Ad-hoc networks for vehicles called vehicular networks to support ITS applications. Among existing ITS applications, we focus in this paper on improving road safety based on vehicular inter-communications for collision avoidance. More specifically, we study here the sophisticated ACO alternative called AntHocNet and compare it to other routing protocols for ad-hoc networks (Amita & Mayank, 2007).

This paper is structured as follows: in Section 2 we review the specific problems that arise in the complex applications we have in mind, and that metaheuristics should solve. In Section 3 we present the operation principles of the basic ACO algorithm, together with some of its extensions. Section 4 presents the AntHocNet algorithm and explains its behavior. Section 5 goes deeper into the analysis of AntHocNet according to complex applications requirements. A conclusion and future directions are presented in Section 6.

2. METAHEURISTICS FOR EMERGENT COMMUNICATION TECHNOLOGIES

Optimization problems are among the greatest challenges for emergent communication technologies, especially under conditions of multiple constraints and multicriteria optimization objectives. Metaheuristics are recognized as a powerful approach capable of optimizing the QoS of complex communication networks with challenging environments. Metaheuristic algorithms have been applied for this purpose in wireless networks, in ad-hoc and mobile networks, and in optical networks. We study specifically in this paper the AntHocNet metaheuristic dedicated to ad-hoc networks.

2.1. Metaheuristics for Wireless Networks

Evolutionary computing approaches such as Genetic Algorithms (GAs) and ACO algorithms have been proposed to solve numerous optimization problems in the field of wireless networks including mobile ad-hoc networks (Montana & Redi, 2005), cognitive radio (Zhang, Xie, & Guiyang, 2008) and cellular networks (Meunier, Bachelet, Talbi, & Caminada, 2001). GAs can be extremely useful for automated selection of parameters for network optimization to meet multiple criteria (Guliashki, Toshey, & Korsemov, 2009), such as minimal transmission delay and energy saving.

Within the area of wireless networks, the ACO algorithm has been studied particularly for dynamic routing. This algorithm is based on the perception of the quantities of what are called “pheromones” represented by a variable to be adapted in order to guide the search for the optimal path. Different variants of ACO have been defined for wireless and ad-hoc networks including ARA (Ant-based
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