Ad Hoc Networks 000 (2016) 1–9

Contents lists available at ScienceDirect

Ad Hoc Networks

journal homepage: www.elsevier.com/locate/adhoc

A micro-artificial bee colony based multicast routing in vehicular ad hoc networks

Xiu Zhang[a,b], Xin Zhang[a,b,*], Cheng Gu[a,b]

[a] College of Electronic and Communication Engineering, Tianjin Normal University, Tianjin, China
[b] Tianjin Key Laboratory of Wireless Mobile Communications and Power Transmission, Tianjin Normal University, Tianjin, China

ARTICLE INFO

Article history:
Received 12 April 2016
Revised 16 June 2016
Accepted 18 June 2016
Available online xxx

Keywords:
Vehicular ad hoc network
Artificial bee colony
Multicast routing
Quality of service
Steiner tree

ABSTRACT

Vehicular ad hoc networks (VANETs) have drawn great attention in wireless communications. Prompt and reliable vehicular communication is a must to provide a good service. Routing is the key problem in information transmission of VANETs. This paper studies quality of service (QoS) constrained multicast routing problem. This problem has been proved to be NP-complete problem, and swarm intelligence algorithms are more suitable than classical algorithms. A micro artificial bee colony (MABC) algorithm is proposed to deal with the problem. The QoS constraints include maximize network lifetime and minimizing delay cost. Multicast routing is abstracted to a continuous optimization problem. Then, it is linked with MABC. Numerical simulation is implemented on a traffic scenario with three instances. Results show that the MABC algorithm successfully attains the optimal routes. Moreover, the routing framework can be applied in real time given the network structure does not change too frequently.

1. Introduction

Hybrid wireless network is formed by wireless nodes and base stations [1]. Wireless networks without support from the fixed infrastructure are known as ad hoc networks. Due to the lack of infrastructure, the data is forwarded to the destination via a multi-hop fashion. Quite often, the ad hoc network has been studied in optimization [2], target detection [3,4], etc. In some scenarios, a set of base stations are connected by wired links and placed within the ad hoc networks to form a wired infrastructure, aiming to enhance the whole network performance. This resulting network is referred to as a hybrid wireless network. Due to the dynamic nature of such network, quite often computational intelligence approaches such as fuzzy logic systems [5–7] and evolutionary computing could be applied to optimization in hybrid wireless networks. In this paper, we are interested in applying evolutionary computing (artificial bee colony) to Vehicular ad Hoc Network (VANET).

Vehicular ad hoc networks (VANETs) have drawn great attention in wireless communications. Typical application scenarios of VANETs include military communications, where base stations could not be built ahead of war area; traffic status reports, where car traffic happens in rush hour; emergency services, where a temporary network is established to assure the communication of relief workers and medical staff; sensor networks, which connect sensors and control center. In VANETs, vehicles are able to arrange themselves to fulfill the application requirements based on the current situations. To support information transmission among vehicles, wireless communications is clearly the primary method. In VANETs, each vehicle is assumed to contain necessary equipments to communicate with nearby vehicles in a short distance. Long distance communication in VANETs is usually stuck in some signal propagation effects, which could be overcome by multi-hop communication. Due to the mobility feature of vehicles and the lack of fundamental architectures, the real time status of networks is hardly to acquire. On the other hand, the connectivity in the networks is an essential basis for information exchange and application requirements. Thus, routing is the key problem in ad hoc network fields. A good routing protocol presents reliable performance in receiving and sending messages from a source node to a destination node [8]. Because multicast routing could effectively organize network resources, reduce network congestion, and node work load, researches concerning multicast routing is meaningful and valuable in VANETs.

VANETs are often expressed as a graph $G = (N, E, W)$, where N is a set of vertex, $W = \sum_{e \in E} w_e$ is weight function of defined on edge set E. Based on graphic theory, the design of multi-hop routing has recently received great attention. In [9], the routing

* Corresponding author.
E-mail addresses: zhang210@126.com (X. Zhang), tjnumark@126.com (X. Zhang), 15620270595@163.com (C. Gu).

http://dx.doi.org/10.1016/j.adhoc.2016.06.009
1570-8705/© 2016 Published by Elsevier B.V.

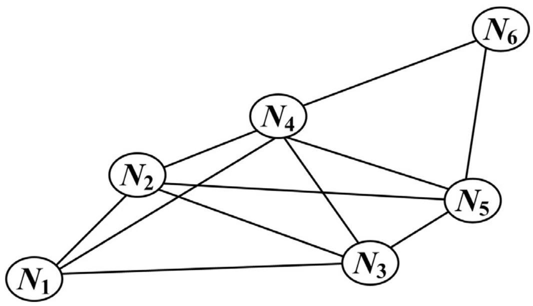

Fig. 1. Example of initializing a binary string.

algorithms and protocols are classified into three types: connected dominating set, disjoint sets, and Steiner minimum spanning tree. Most of these problems are NP-hard or NP-complete.

Assume a VANET has been transformed to a graph G with n nodes and $C > 0$ is a constant number, the Steiner minimum tree (SMT) problem refers to add m new nodes to G such that the resulting minimum spanning tree has the minimum number of additional nodes (i.e., m) and the edge length in the tree is equal to or less than C. The additional nodes are named Steiner points. This problem is also described as "Steiner tree problem with minimum number of Steiner points and bounded edge-length (STP-MSPBEL) [10]". When the manhattan distance is used in the network, the SMT problem is known to be NP-hard.

Due to the failure of sensor nodes, fast moving vehicles, or vehicle breakdown, VANETs require a routing path between source node and destiny node being frequently reconstructed. Transmission based on tree structure is the most popular one in multicast routing. Once the multicast tree is built, the information generated by source node can be sent to end nodes. Source-based tree and core-based tree (i.e., shared tree) are two common types in multicast tree. Routing algorithm is a crucial part of routing protocol, which is in charge of constructing a tree linking source nodes and destiny nodes.Quality of service (QoS) is a must when routing algorithm builds pathes. QoS mainly contains path length, bandwidth, delay, delay jitter and packet loss ratio.

As quality of service (QoS) constrained multicast routing has been proved to be NP-complete problem [11,12], classical routing algorithms become unable to handle this problem. Recent researches focus on heuristic algorithms and computational intelligence algorithms. Typical computational intelligence paradigms include particle swarm optimization [13], differential evolution [14], neighborhood field optimization [15]. Artificial bee colony (ABC) is a popular computational intelligence algorithm. This paper concentrates on modifying ABC to tackle the SMT problem in multicast routing.

To efficiently deal with the SMT problem, this paper designs a micro-ABC method with binary representation. The method contains a micro bee colony, which saves computational time in each cycle compared with the use of a regular colony size. Moreover, two novel search equations are proposed to improve the convergence speed of the algorithm. The performance of the algorithm is studied on a VANET with 16 cars.

The paper is organized as follows. Section 2 reports the SMT problem and related works. Section 3 gives the proposed algorithm and its analysis. Section 4 shows the numerical simulation setting and results. Section 5 gives the conclusion.

2. Problem overview and related works

VANET is featured with exchanging information amongst vehicles in real time. It requires data packets have to travel through the vehicular network from source nodes to destiny nodes. Routing protocol is crucial in the operation of VANET. Information transmission between a source node and an end node is easily resolved by shortest path algorithm given the network topology. However, the transmission task in VANET are mainly a source node broadcasting to multiple end nodes, which is well known as multicast routing.

Based on the implementation of multicast routing, the algorithms can be classified to centralized algorithm and distributed algorithm. In the former, source nodes is in charge of find a proper route based on the status information that it acquires; while the latter requires each node has local status information instead of mastering the whole network status, and the computation of route is accomplished by inter-sites on the route. Neither could completely outperform the other. Users have to decide which one is more proper depending on the practical necessity.

The information transmission in multicast communication is realized by building a multicast tree. Among all possible multicast trees, the most economic one evaluated by QoS indices is called Steiner minimum tree. The SMT problem is described as follows. Let $G = (N, E, W)$ denote an undirected graph, where $W = \sum_{e\in E} w_e$ is weight function defined on edge set E. Under the condition that auxiliary nodes are allowed to add to G, SMT is equivalent to find the minimum spanning tree of graph $\bar{G}$, where $\bar{G}$ is G with auxiliary node set $\bar{N}$ and updated edge set $\bar{N}$. Since the distance in VANETs is generally measured by Euclidean metric, the SMT problem is also called ESMT [11].

Kompella et al. proposed a heuristic multicasting routing for multimedia communications [16]. Sun and Langendorfer proposed a constrained Dijkstra heuristic algorithm for delay-constrained multicast routing algorithm [17]. Parsa et al. proposed a bounded shortest delay-constrained multicasting algorithm [18]. Gutierrez-Reina et al. studied a railway scenario, which is a kind of MANETs, and applied GA to optimize the network topology [19]. Natarajan and Rajendran proposed a modified Dijkstra algorithm to deal with an advanced optimized link state routing protocol [20].

Recently, researchers attempted to handle multicast routing by computational intelligence approaches [21]. Hwang et al. used genetic algorithm (GA) to deal with multicast routing [22]. Yen et al. considered multicast routing with multiple QoS constraints in mobile ad hoc networks (MANETs) and proposed an energy-efficient GA for this kind of problems [23]. Based on Tabu search, Forsati et al. studied several methods to tackle the bandwidth delay-constrained least-cost multicast routing [24]. Toutouh et al. studied the optimal parameter setting in the optimized link state routing protocol of MANETs, where GA, differential evolution (DE), particle swarm optimization, and simulated annealing are applied to do the optimization [25].

This paper attempts to tackle QoS multicast routing protocol in VANETs. Specifically, minimum cost and maximum network life time are taken as measurements to access the QoS of network. SMT is constructed linking source nodes and destiny nodes. In multicast routing, it is usually assumed that one source node send messages to multiple end nodes. Unlike building a network architecture, Steiner points are not permitted to be placed anywhere under the coverage area of a vehicle. At a time slot, the positions of vehicles in VANETs are relatively stable, though they may change in the next time slot after driving. The candidate Steiner points are those in network graph G excluding source and destiny nodes. Fig. 1 presents a VANET example including 6 nodes and 11 edges. All nodes are numbered in order. Given node N_1 is the source and node N_5 is the end. The SMT problem becomes to select middle nodes from set $\{N_2, N_3, N_4, N_6\}$ such that the communication cost is minimized. Each node in the network can dynamically very its emitted energy. In case a node becomes a inter-site in a routing tree, we suppose that it could adapt its radiation energy to different transmission paths. Moreover, the topology of a VANET is