Information Sciences 295 (2015) 67–90

Contents lists available at ScienceDirect

Information Sciences

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

Ant colony optimization based enhanced dynamic source routing algorithm for mobile Ad-hoc network

Shubhajeet Chatterjee [a], Swagatam Das [b,*]

[a] Department of Electronics and Communication Engg, Institute of Engg. & Management, Kolkata 700091, India
[b] Department of Electronics and Communication Science Unit, Indian Statistical Institute, Kolkata 700108, India

ARTICLE INFO

Article history:
Received 3 July 2013
Received in revised form 19 August 2014
Accepted 24 September 2014
Available online 7 October 2014

Keywords:
ACO routing
DSR (Dynamic Source Routing)
Mobile Ad-hoc Networks (MANETs)

ABSTRACT

Due to the dynamic nature of the Mobile Ad-hoc Network (MANET), routing in MANET becomes challenging especially when certain QoS requirements (like high data packet delivery ratio, low end to end delay, low routing overhead, and low energy consumption) are to be satisfied. Though a number of routing protocols have been proposed aiming to fulfill some of these QoS requirements but none of them can support all these requirements at the same time. In this paper, we propose an enhanced version of the well-known Dynamic Source Routing (DSR) scheme based on the Ant Colony Optimization (ACO) algorithm, which can produce a high data packet delivery ratio in low end to end delay with low routing overhead and low energy consumption. In our scheme, when a node needs to send a packet to another node, like DSR, it first checks the cache for existing routes. When no routes are known, the sender node locally broadcasts the Route Request control packets (called the Req.Ant packets) to find out the routes. This is similar to the biological ants initially spreading out in all directions from their colony in search of food. Now, the ants, after finding the food source, come back to the colony and deposit pheromone on their way so that other ants get informed about the paths. Similarly, in our routing scheme, the Req.Ant packets propagate through the network according to our novel route discovery scheme and gathers information of the route (i.e. total length of the route, congestion along the route and end to end path reliability of the route), till it reaches the destination node. When the destination node receives a Req.Ant packet, it sends back Rep.Ant (Route Reply control packet) which consists the route information of the corresponding Req.Ant to the source node through the same route. On receiving such Rep.Ant packets from different routes, the source node comes to know about those routes. Under the ant colony framework, the best route is selected by the pheromone level of the route. Similarly, here we calculate the pheromone level of a route based on the number of hops in the route, the congestion along the route and end to end path reliability of the route.The route with the highest pheromone count will be selected for data packet delivery. We also propose a novel pheromone decay technique for route maintenance. The simulation results show that our ACO based Enhanced DSR (E-Ant-DSR) outperforms the original DSR and other ACO based routing algorithms.

* Corresponding author.
E-mail addresses: chatterjeeshubhajeet@gmail.com (S. Chatterjee), swagatam.das@isical.ac.in (S. Das).

http://dx.doi.org/10.1016/j.ins.2014.09.039
0020-0255/© 2014 Published by Elsevier Inc.

1. Introduction

In recent days, the Mobile Ad-hoc Networks (MANETs) have experienced a burgeoning growth in popularity because it can provide instant wireless networking solution where no pre-deployed infrastructure exists. The requirement for MANETs emerge from situations where nodes like cell phones and laptops need to cluster together and create a network that can support services like messaging, resource sharing, and file-sharing. Hence the primary goal in a MANET routing is to quickly and efficiently establish one (unicast) or more (multicast) reliable end-to-end paths (i.e. routes) between the nodes so as to facilitate their reliable communication. Also, due to limited battery (i.e. energy) capacity of the individual nodes, the routing scheme should not consume high amount of energy.

But the routing in MANET faces several challenges [13]. First of all, due to unpredictable and random movement of the nodes the network topology can experience dynamic changes. Secondly the protocols must be adjusted as a node joins or leaves the network. Finally, although no guarantee of service can be provided, the protocol should be able to maximize the reliability of the data packets in the network for the given conditions.

Due to the fast changing nature and the ad hoc necessity of the network, no centralized solution is possible which can decide the best route based on different parameters like path length, congestion, and load. Also no single node can take up the job of centralized manager due to their limited energy and limited processor capabilities. Thus, routing in MANET is a challenging topic of research.

In DSR [31] scheme, when a source needs to send a packet to a destination node, it first checks the cache for existing routes. When no routes are known, the Sender node broadcasts Route Request (RREQ) control packets to find out the route. This RREQ message consist sender's address, destination's address and a unique request ID given by the sender node. These packets are flooded through the network till it reaches to the destination node. When the destination node receives a RREQ, it sends back Route Reply packet (RREP). On receiving this RREP packet the source node stores that route into its cache memory. Now the shortest path is chosen for data delivery. For route maintenance,when a node fails to forward packet through a particular link, it sends a Route Error message to the sender node.On receiving this Route Error message, the sender node updates its route cache. This routing protocol has several drawbacks: low data packet delivery ratio in high mobility scenario due to frequent link breakage phenomena, high end to end delay of packet delivery and high routing overhead due to inefficient route discovery scheme and it consumes very high amount of energy. Here, we will try to enhance this DSR scheme by proposing a novel route discovery and route maintenance technique which will outperform not only the DSR but also other popular routing protocols.

ACO algorithm is developed aiming to search for an optimal path in a graph, based on the behavior of harvesting ants seeking a path between their colony and a source of food [18]. Biologically ants communicate and exchange information with each other by laying down a volatile chemical factor called pheromone. While searching for food each ant takes a random walk from its anthill. Different ants follow different routes to reach the food in a random manner. On the way back to the anthill, ants deposit pheromone on their trajectories to allow their fellow ants to detect the leftover food and thus, reinforcing the pheromone on the trail. In this way, a number of paths might exist from the nest to the food. Always the reinforcement in shorter tracks tends to be more attractive due to shorter end-to-end travel time. But when a previously short route gets blocked or lengthened due to an obstacle in the route, the alternate short routes get strengthened with higher pheromone content. However, as the time passes on, the pheromone on the trail gradually evaporates. Consequently, when the food is exhausted, new trails are not marked by returning ants, and the pheromone level steadily reduces. Such stigmergic behavior helps ants to adapt to changes in their environment.

The idea behind applying ACO in DSR protocol is to discover and maintain the best routes among the nodes.

Although ACO requires limited computation and power from the individual nodes, it can still provide effective routing. Due to the self-organizing and adapting capabilities of the artificial ants ACO can keep the routing tables efficiently updated.

The main contributions in this paper can be summarized in the following way:

(1) We propose a novel strategy to measure the reliability of a wireless link in a dynamic network like MANET.
(2) We enhanced a previously proposed strategy for congestion level measurement of a link.
(3) We propose a novel route discovery scheme which not only ensure low end to end delay of packet delivery but also overcomes several conflicts (e.g. the looping conflict and void region conflict) of the previous schemes. This route discovery scheme can be applied in other reactive routing schemes also (AODV [45], TORA [43], LMR [17], etc.).
(4) We propose a novel route choosing technique based on length, congestion and reliability of the path.
(5) We propose a new pheromone decay technique for route maintenance which could directly be used also for a number of other ACO based routing protocols (Ant-DSR [5], Ant-Hocnet [22], Ant-AODV [2], etc.).
(6) We analyze the energy consumption of our proposed scheme and estimate the required energy for a node.
(7) Finally, we evaluate our scheme in a simulation environment. The pseudo codes are given in the appendix for future use.

The paper is organized in the following way. Section 2 provides a brief but comprehensive overview of the related works. Section 3 describes our proposed approach in sufficient details. The simulation results have been presented and discussed in Section 4. Finally the paper has been concluded in Section 5.