A Novel Heuristic Routing Algorithm Using Simulated Annealing in Ad Hoc Networks

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Abstract. Multi-constrained quality-of-service routing (QoSR) is to find a feasible path that satisfies multiple constraints simultaneously, as an NPC problem, which is also a big challenge for ad hoc networks. In this paper, we propose a novel heuristic routing algorithm based on Simulated Annealing (SA_HR). This algorithm first uses an energy function to translate multiple QoS weights into a single metric and then seeks to find a feasible path by simulated annealing. The paper outlines simulated annealing algorithm and analyzes the problems met when we apply it to QoSR in ad hoc networks. Theoretical analysis and experiment results demonstrate that the proposed method is an effective approximate algorithms showing good performance in seeking the (approximate) optimal configuration within a period of polynomial time.

1 Introduction

Ad hoc networks are dynamic multihop wireless networks that are established by a group of mobile nodes on a shared wireless channel by virtue of their proximity to each other. Ad hoc wireless networks are self-creating, self-organizing, and self-administering. The attractive infrastructure-less nature of mobile ad hoc networks has gained a lot of attention in the research community. Most applications that attract interest for use in current wired networks (e.g., video conferencing, on-line live movies, and instant messenger with camera enabled) would attract interest for ad hoc networks as well. Numerous challenges must be overcome to realize the practical benefits of ad hoc networking. These include effective routing, medium (or channel) access, mobility management, power management, security, and, of principal interest here, quality of service (QoS) issues. Cost-effective resolution of these issues at appropriate levels is essential for widespread general use of ad hoc networking.

QoS guarantees can be attained only with appropriate resource reservation techniques. The most important element among them is QoSR. The main function of QoSR is to find a feasible path that satisfies multiple constraints for QoS applications (e.g., multimedia transportation and real-time traffic). In wired networks, there are many QoSR methods which has been proposed [1~3]. But they can not been directly applied to ad hoc networks because unlike the wired network, the network topology may change constantly, the available state information for routing is inherently imprecise, and the network itself is noncentralization. QoS for ad hoc networks has been previously explored by [3~8]. Path computation algorithms in these literatures care

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about only a single metric, such as delay or hop-count, and most of them only deal with the best effort data traffic. SBR [4] fulfills both signal-to-interference (SIR) and bandwidth requirements from different multimedia users in ad hoc mobile networks. In [5], the proposed approach adopts bandwidth as a QoS metric. In CEDAR [7], the bandwidth is used as the only QoS parameter for routing. The proposed algorithm has three key components: a) the establishment and maintenance of the core of the network for performing the route computations; b) propagation and use of bandwidth and stability information of links in the ad hoc network; and c) the QoS route computation algorithm. While the core provides an efficient and low-overhead infrastructure to perform routing and broadcasts in an ad hoc network, the increase/decrease wave-based state propagation mechanism ensures that the core nodes have the important link state they need for route computation, without incurring the high overhead of state maintenance for dynamic links. The QoS routing algorithm is robust and uses only local state for route computation at each core node. In [8], the proposed approach selects a network path with sufficient resources to satisfy a certain delay (or bandwidth) requirement in a dynamic multihop mobile environment while working with imprecise state information. Multiple paths are searched in parallel to find the most qualified one. Fault tolerance techniques are brought in for the maintenance of the routing paths when the nodes move, join, or leave the network. Algorithms proposed there consider not only the QoS requirement, but also the cost optimality of the routing path to improve the overall network performance. There the delay and bandwidth are used for QoS routing but not simultaneously.

More than one QoS constraints often make the QoSR problem NP complete [9]. Approximated solutions and heuristic algorithms have been successfully applied to solve many combinatorial optimization NPC problems. Inspired from this, we propose a novel heuristic routing algorithm based on simulated annealing (SA_HR) for multi-constrained routing in ad hoc networks. Different from the non-linear programming methods, SA_HR is a heuristic method which uses explicit rules to find feasible routes.

In ad hoc networks, finding a loop-free path as a legitimate route between a source-destination pair may become impossible if the changes in network topology occur too frequently. Rapid topology changes militate against QoS guarantees. Let T_u and T_{uc} denote the interval between two consecutive topology change events and the time it takes to complete the calculation and the propagation of the topology updates resulting from the last topology change, respectively. Only the ad hoc network that is combinatorially stable is considered. Here combinatorially stable means $T_{uc} < T_u$. We call QoS in this kind of circumstance Soft QoS [8] which is better than best effort service rather than guaranteed hard QoS. Therefore, combinatorial stability must first be met before we can consider providing QoS service. There are many networks that satisfy this requirement. For example, consider a network made up of students in a class; students may join the lecture late, some may leave the classroom, but most stay in the stationary position. If the just computed feasible route ceases to exist during the corresponding topology update, the QoS guarantee becomes meaningless.

The paper is organized as follows. Section 2 introduces the problem formulation and the basic principle of SA. The novel method based on SA is proposed in Section