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Adaptive two-way uniform partition for multicast routing problem with separate paths in ad hoc networks

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Abstract

Finding a near-optimal routing solution for multicast requests is a challenge for supporting different multicast applications including video and group communications over wireless ad hoc networks. A heuristic partitioning algorithm for solving the multicast routing problem with separate paths in ad hoc networks is presented. We consider scheduling a set of multicast requests which may have a source node with multiple destinations respectively through a wireless network. Our heuristic method for partitioning arbitrary routing requests is both effective in finding a near-optimal solution, and efficient to solve large multicast requests. Our simulation shows that the average overall latency reduces up to 38%. We also find that the handling scales up well from 8 nodes to 64 nodes.

Keywords: Multicast; Ad hoc networks; Wireless networks; Partition scheme

1. Introduction

1.1. Definition of the problem

A wireless ad hoc network is a collection of wireless mobile nodes communicating with each other without infrastructure support. Each node acts as a router and relays the packets by a multi-hop transmission, and each node can directly communicate with its neighbor nodes within radio range. There are many challenges for supporting different multicast applications including video communications and hotspot Internet accesses over wireless ad hoc networks. Generally speaking, available bandwidth is one of the challenges in such a precious resource in mobile ad hoc networks. In a multicast session, a multicast source transmits packets to a group of multicast receivers with bandwidth saving, reduction in transmission overhead and power saving in a forwarding manner (Ayman, Roca, & Inria, 2003; Dolev, Schiller, & Welch, 2006; Khisti, Erez, & Wornell, 2006; Sandrasegaran & Prag, 1999; Viswanath, Obraczka, & Tsudik, 2006). In this paper, we consider a set of multicast requests to be routed in a certain waiting time rather than determine the route requests in a first come first serve manner. Each request has a single multicast source with perhaps several multicast receivers, and each request may have different multicast source and receivers. We define the multicast routing problem as finding a near-optimal multicast route through an ad hoc network for a given set of multicast requests with multiple paths in a period waiting time. In this paper we present a heuristic partitioning algorithm for solving the multicast routing problems with multiple paths in ad hoc networks. Our adaptive two-way uniform partition algorithm not only finds a near-optimal multicast routing solution for multicast applications, but also allows a backup solution path for transmitting the request bandwidth in a multiple path network environment.

1.2. Paper contributions

This paper has the following contributions: given a set of multicast requests through a wireless network, the routes of multicast requests partition into two near-optimal

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sub-solutions, so as to minimize the usage of the total bandwidth utilization of the multicast requests. Several important practical problems are energy efficient multicasting, multicast video communication and cooperative multicasting, so as to minimize the number of conflict links between each multicast requests (Cheng, Cao, & Wang, 2006; Dolev et al., 2006; Kim & Kim, 2005). For energy efficient multicasting, intermediate nodes are used to forward the multicast packets from a multicast source to a set of multicast members. If we minimize the number of conflict links between these requests, thus we can save energy of all intermediate nodes in the multicast trees (Li & Li, 2006; Liang, 2006). The major challenge for supporting multicast video communication over ad hoc networks is the mobility, thus our proposed method established multicast routes efficiently and robustly (Misra, Poddar, Nandi, Santra, & Panda, 2005; Wei & Zakhor, 2004, 2007). Cooperative multicasting is a new popular application for wireless networks with mobile nodes. Our adaptive two-way uniform partition algorithm can be applied for the increasing multicast requests in a dense wireless network to determine the near-optimal solution for multicast requests (Dasdan & Aykanat, 1997; Kernighan & Lin, 1970).

The remainder of the correspondence is organized as follows. Section 2 introduces previous researches for multicast routing with split paths. The adaptive two-way uniform partition algorithm is stated in Section 3. We present our simulation results and performances via NS simulation in Section 4. Finally, we conclude with discussion and future works in Section 5.

2. Previous researches for multicast routing with split paths

There are several schemes to improve the performance of individual multicast groups in hybrid networks which integrate cellular networks and ad hoc networks. A network model for multicast admission control by using an integer linear programming formulation and a polynomial-time dynamic algorithm to optimize bandwidth saving and maximize the network utilization (Lao & Cui, 2006). In self-stabilizing group communication systems, mobile agents are required to collect locations of mobile nodes to allocate bandwidth for multicast groups (Dolev et al., 2006). A heuristic multicast algorithm (DDVMA) is proposed to satisfy the multicast end-to-end delay constraint and minimize delay variation for multicast requests (Wei & Zakhor, 2004). In order to split the multicast requests into two disjoint multicast trees, both the minimum spanning tree and parallel multiple nearly-disjoint multicast tree protocol are proposed to achieve reasonable connectivity (Li, Li, & Lau, 2006).

Multicast communication services refer to the efficiency to transmit information, such as video streaming, with several multicast members at the same time using the same backbone. Therefore, one of the point-to-multiple-point routing (PMRP) problems in heterogeneous wired–wireless networks is finding a near-optimal routing for simultaneous group communication requests through a ubiquitous Internet access environment. This problem is known to be a NP-complete problem. Galiasso and Wainwright (2001) and Zhu et al. (1998) proposed a hybrid genetic algorithm for solving one point to multipoint routing problem, in order to schedule a set of multicast requests which has a single source and multiple receivers with single split path. For the previous researches, this problem was not only treated each request as a whole, but also found the path of each sub-communication by using a heuristic Steiner tree algorithm and a chromosome encoding scheme. Fig. 1 shows an example gene encoding for implementing a chromosome encoding of five multicast requests. Pablo Galiasso and Zhu et al. first designed a chromosome encoding with request segment and percentage segment for the multicast requests, and then they developed three crossover operators and two types of mutation operations with a maximum number of 200 generations to determine the best order of multicast requests for bandwidth utilization.

Since a simple PMRP problem can be treated as several point-to-point routing requests, a Ford and Fulkerson max flow–min cut algorithm (Bui & Moon, 1996; Kernighan & Lin, 1970) treats a network topology as a graph which link cost corresponds to maximum bandwidth capacities between a source–receiver pair. Therefore, we can separate these links/edges into two disjoint subsets. In order to get the minimal cut capacity for separating into two subsets, the max flow–min cut method is applied to obtain the maximal flow values between any pair of nodes. To see this supposes that network topology has n nodes to be partitioned into h subsets of size s ($h^* s = n$). The total number of possible cases is

$$\frac{1}{h!}\binom{n}{s}\binom{n-s}{s}\cdots\binom{2s}{s}\binom{s}{s}.$$

Where there are $\binom{n}{s}$ ways of the first subset and $\binom{n-s}{n}$ ways for the second, and so on. For example, if $n = 40$ and $s = 10$ ($h = 4$), it is more than 10^{20} cases in each a network topology. It is almost impossible to approach finding an exact solution in an ordinary amount of computation. Therefore a heuristic partition method can produce good solutions quickly by finding a two-way partition of n nodes with a given $2n$ vertices graph into two-subset solutions.

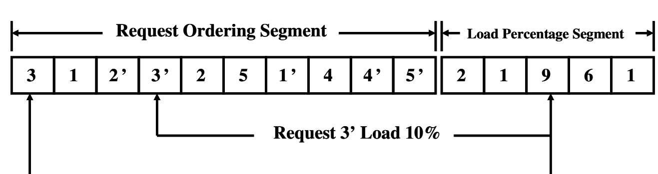

Fig. 1. A gene encoding example for five multicast requests.