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A dynamic programing solution for QoS routing in wireless ad hoc network with energy constraints

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Abstract

In mobile ad hoc networks (MANETs), it is essential to provide quality of service (QoS) guarantee for diverse multimedia applications. Most researches focus on the QoS metrics but neglect the energy constraints of MANET itself which is a fairly important problem. In this paper we aimed to solve the battery limitation and bandwidth constraints in MANETs using dynamic programming method. We first construct a QoS routing model based on dynamic programming and then make a detailed description of the algorithm. Simulations are conducted to evaluate the performance of the proposed algorithm.

Keywords ad-hoc, QoS routing, dynamic programming

1 Introduction

A MANET is a self-configuring temporary multi-hop system with a set of mobile terminals like wireless transceivers. MANETs are widely used in the military fields, wireless sensor networks, emergency search and so on, thanks to its swiftness, self-organization and low costs. With the development of networks and high demands of users, providing QoS support has received much attention [1–2]. QoS intends to guarantee the end-to-end communication on propagation delay, bandwidth and so on. How to make use of wireless network resources rational and effective in order to provide QoS guarantee for diverse multimedia applications is now an essential issue [3].

In the traditional research, researchers focus on the chosen of QoS metrics which includes available bandwidth, end-to-end delay, packet loss rate and so on. But the mobility of nodes and surrounding environment have great impact on the state of links in MANETs, especially in the large scaled networks. So, it is difficult to obtain, refresh and maintain link parameters. Furthermore, finding a route that satisfies multiple QoS constraints is inherently difficult. It has been established that meeting more than one QoS constraint is considered non-deterministic polynomial (NP)-Complete [4]. As a result, it is not advisable to design a multi-parameter method for QoS routing. In MANETs, nodes communicate with each other through wireless channels which results in a limited bandwidth. In this paper, we considered bandwidth as an important QoS parameter. In general, researches on QoS routing have not usually taken into consideration the consumption of battery energy which represents one of the greatest constraints in MANETs. Most network equipments in MANETs are of small volume and their battery energy is extremely finite. In some applications the ability of battery even determines the lifetime of the whole system [5]. So how to make use of energy effectively and improve the lifetime of nodes becomes a crucial problem recently. In this paper we proposed a QoS routing approach based on dynamic programming method and take into account of energy consumption and bandwidth as our main starting points.

The dynamic programming approach is an effective theory to solve the problem of multi-stage decision-making. The theory is translating a multi-stage

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problem into single-stage correlative problems. When the problems of all the stages are solved, the multi-stage problem is accordingly processed. A sub-strategy of the optimum strategy which meets the constraints, for its initial state and final state, must be optimum [6–7]. When an optimum routing meeting the QoS constraints is established, its sub-routing is certainly optimal. As a result, repeated computation is avoided and resources are greatly saved. In the meanwhile, the dynamic programming algorithm has a low time complexity and less energy costs compared with other methods during the process of routing which is truly necessary for energy saving guarantee.

2 Traditional dynamic programming method

In dynamic programming, the solution of problems can be regarded as a decision process. This process is divided into several different stages which are correlative and each has some solutions to be chosen. The decision maker needs to choose a suitable scheme in each stage to get a best result in the decision process. Fig. 1 shows a common dynamic programming model.

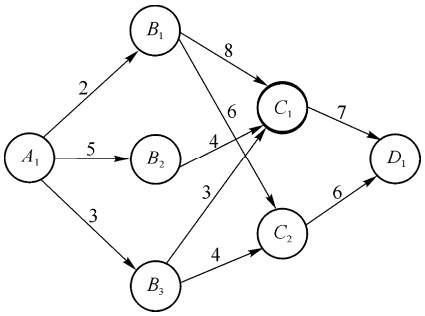

Fig. 1 A dynamic programming model

This figure has a feature that the nodes can be divided into four sets A, B, C, D and all the sides are belonging to two adjacent sets. As a result, the sides will be divided into three categories $(A \to B, B \to C, C \to D)$. We need to choose one side in each category to form a path from A_1 to D_1, and make the path the shortest one. This is called a multi-stage decision-making problem.

Dynamic programming aims to divide a multi-stage decision-making problem into a series of single phase to solve respectively and finally join them together to get the solution of the whole problem.

In Fig. 1, the process from *A* to *D* can be divided into three stages: $A \to B$, $B \to C$ and $C \to D$. If one path is selected as the shortest, apparently any sub-route between two intermediate nodes in this path must be optimal. So if we have got the lowest paths from $A \to C_i$ and $C_i \to D$ $(i = 1, 2)$, we can join the two paths when *i* is 1 and 2, and then choose the shorter one as the lowest path from *A* to *D*. While if we want to get the lowest path from $A \to C_i$, we need to know the lowest path from $A \to B_i$. So if we get the lowest path from $A \to B_i$, we will calculate the lowest path from *A* to *D*. This is the basic thought of the dynamic programming method.

3 QoS routing model based on dynamic programming

The problem to search a routing path with low energy consumption and high bandwidth guarantee in MANETs is to find an optimum path from the source to the destination. The dynamic programming method is translating a multi-stage problem into single-stage correlative problems, so it is very appropriate to solve the QoS routing problems in MANETs. In this paper, we propose a QoS routing model based on dynamic programming in Fig. 2.

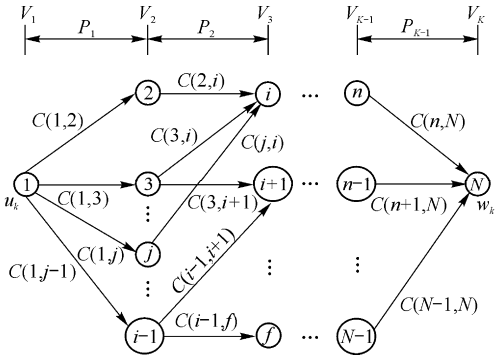

Fig. 2 A QoS routing model based on dynamic programming

3.1 Related definition

We assume that there are *N* nodes in the network. First the nodes are divided into $K(K \geqslant 2)$ disjoint sets $V_k(k = 1, 2, ..., K)$, where there is only one source node *uk* and one destination node w_k in set V_1 and V_K. The K sets divide the routing into $K-1$ stages represented as *P*. The routing from source node u_k to V_2 is called stage 1, represented as P_1. So the routing from V_{K-1} to destination node w_k is called stage $K-1$, represented as P_{K-1}. Then each node is numbered as follows: first, source node u_k is numbered as No.1, and then nodes in stage V_2 are numbered from No.2, then nodes in stage V_3 follow the last number in stage V_2