Available online at www.sciencedirect.com
ScienceDirect
Progress in Natural Science 18 (2008) 331–336
Progress in Natural Science

Special report

Multiple constraints QoS multicast routing optimization algorithm in MANET based on GA

Baolin Sun [a,c,*], Shangchao Pi [b], Chao Gui [a], Yue Zeng [d], Bing Yan [a], Wenxiang Wang [c], Qianqing Qin [c]

[a] School of Computing, Hubei University of Economics, Wuhan 430205, China
[b] College of Science, Zhongyuan University of Technology, Zhengzhou 450007, China
[c] State Key Laboratory of Information Engineering in Surveying, Mapping & Remote Sensing, Wuhan University, Wuhan 430079, China
[d] Department of Computing, Jiangxi Vocational College of Finance and Economics, Jiangxi 332000, China

Received 29 October 2007; received in revised form 15 November 2007; accepted 15 November 2007

Abstract

Usually multiple quality of service (QoS) guarantees are required in most multicast applications. This paper presents a multiple constraints algorithm for multicast traffic engineering in mobile ad hoc networks (MANET). The proposed algorithm is a new version of multiple constraints QoS multicast routing optimization algorithm in MANET based on genetic algorithm (MQMGA). The proposed MQMGA can optimize the maximum link utilization, the cost of the multicast tree, the selection of the long-life path, the average delay and the maximum end-to-end delay. Experimental result shows that the approach is efficient, has promising performance in multicast traffic engineering and for evaluating the route stability in dynamic mobile networks.

Keywords: Ad hoc network; Multicast routing; QoS; Genetic algorithm

1. Introduction

A mobile ad hoc network (MANET) is an autonomous system of mobile nodes connected by wireless links. However, there is no static infrastructure, such as base station, as it is in cell mobile communication. In ad hoc network, if two nodes are not within the radio range, all message communication between them must pass through one or more intermediate nodes. All the nodes are free to move around randomly, thus changing the network topology dynamically [1–11]. They are useful in many situations such as military applications, conferences, emergency search, rescue operations and law enforcement. However, the network topology is unpredictable due to mobility of nodes and the limited available bandwidth. These characteristics require a new way of designing and operating this type of networks. Moreover, for such networks, an effective routing protocol adapting to node mobility as well as possible channel error is critical to provide a feasible path for data transmission [1–9].

Multicast is simultaneous data transmission from a source node to a subset of destination nodes in a computer network. Multicasting can reduce the communication cost for sending the same data to many recipients [1,2,4–6,10–15]. Instead of sending via multiple unicast, multicast reduces the channel bandwidth, sender and router processing and delivery delay. In addition, multicast gives robust communication even if the receiver address is unknown or modifiable without the knowledge of the source within the wireless environment.

In the multicast routing problems, a good routing algorithm finds low-cost tree connecting all of the routers that

* Corresponding author. Address: School of Computing, Hubei University of Economics, Wuhan 430205, China. Tel.: +86 13207194972.
E-mail address: blsun@163.com (B.L. Sun).

1002-0071/$ - see front matter
doi:10.1016/j.pnsc.2007.11.006

have attached host members of multicast group and then routes packet along this tree from a source to multiple destinations according to the multicast routing tree [1–4,6,10–15]. Finding the link tree with the minimum cost is known as the Steiner tree problem in graph theory [1,5]. These approaches can be classified into two categories: group-shared tree, where only a single routing tree is constructed for the entire multicasting group, and source-based tree, where a tree is constructed for each individual sender in the group. In general, the former is efficient for large-scale stable networks; and the latter is useful for small-scale dynamic networks. Due to the increasing importance of wireless networks, the source-based tree approach appears to be more attractive. Moreover, multicast routing problems consist of a single QoS constraint [4–6,9,10,13,14,16] or multiple QoS constraints [6,9,11–13]. In wireless networks, multiple-QoS scenario is more promising.

Entropy [17,18] presents the uncertainty and is a measure of disorder in a system. There are some common characteristics among self-organization, entropy, and the location uncertainty in mobile ad hoc wireless networks. These common characteristics have motivated our work in developing an analytical modeling framework using entropy concepts and utilizing mobility information as the corresponding variable features, in order to support route stability in self-organizing mobile ad hoc wireless networks. The corresponding methodology, results and observations can be used by the routing protocols to select the most stable route between a source and a destination in an environment where multiple paths are available, as well as create a convenient performance measure for the evaluation of the stability and connectivity in mobile ad hoc networks.

Considering that genetic algorithms (GA) are suitable for multiple constraints optimization problems [1,6,11–14]. We will present a multiple constraints algorithm for multicast traffic engineering in MANET in this paper. The proposed algorithm is a new version of multiple constraints QoS multicast routing optimization algorithm in MANET based on GA (MQMGA). Results show that the proposed MQMGA can optimize the maximum link utilization, the cost of the multicast tree, the selection of the long-life path, the averages delay and the maximum end-to-end delay.

2. Network model and routing issues

A network is usually represented as a weighted digraph $G = (N, E)$, where N denotes the set of nodes and E denotes the set of communication links connecting the nodes. $|N|$ and $|E|$ denote the number of nodes and links in the network, respectively. Without loss of generality, only digraphs are considered in which there exists at most one link between a pair of ordered nodes.

In $G(N, E)$, considering a QoS constrained multicast routing problem from a source node to multi-destination nodes, namely given a non-empty set $M = \{s, u_1, u_2, \ldots, u_m\}$, $M \subseteq N$, s is the source node, $U = \{u_1, u_2, \ldots, u_m\}$ is a set of destination nodes. In multicast tree $T = (N_T, E_T)$, where $N_T \subseteq N$, $E_T \subseteq E$, if $C(T)$ is the cost of T, i.e.

Definition 1. The delay of path $p(s, u)$ and the cost of path $p(s, u)$ are

$$D_{p(s,u)} = \sum_{(i,j)\in p(s,u)} d_{ij} \tag{1}$$

$$C_{p(s,u)} = \sum_{(i,j)\in p(s,u)} c_{ij} \tag{2}$$

$$B_{p(s,u)} = \min_{(i,j)\in p(s,u)} \{b_{ij}\}. \tag{3}$$

where d_{ij} is the delay of link (i, j), c_{ij} is the cost of link (i, j), b_{ij} is the bandwidth of link (i, j), and $p(s, u)$ is the path from source node s to destination $u \in U$.

Definition 2. The maximum link utilization of tree T is

$$\alpha_m = \operatorname*{Max}_{(i,j)\in T}((\varphi + t_{ij})/z_{ij}). \tag{4}$$

where φ is the traffic demand, t_{ij} is the current traffic of link (i, j), and z_{ij} is the capacity of link (i, j).

Definition 3. The cost of multicast tree T is

$$C(T_s) = \sum_{u\in U} C_{p(s,u)} \tag{5}$$

Definition 4. The maximum end-to-end delay of multicast tree T is

$$D_s = \operatorname*{Max}_{u\in U}\{D_{p(s,u)}\} \tag{6}$$

Definition 5. The bandwidth of multicast tree T is the minimum value of the link bandwidth in the path from source node s to each destination node $u \in U$. i.e.

$$B_s = \operatorname*{Min}_{u\in U}\{B_{p(s,u)}\} \tag{7}$$

Definition 6. Assume the minimum bandwidth constraint of multicast tree is B, the maximum end-to-end delay constraint of multicast tree is D, given a multicast demand R, then the problem of bandwidth, and delay constrained multicast routing is to find a multicast tree T, satisfying:

(i) Bandwidth constraint: $B_s \geqslant B$;
(ii) end-to-end delay constraint: $D_s \leqslant D$;
(iii) link capacity constraint: $(\varphi + t_{ij})/z_{ij} \leqslant 1$, $\forall (i, j) \in T$.

Suppose $S(R)$ is the set, $S(R)$ satisfies the conditions above, then the multicast tree T which we find is

$$C(T) = \min(C(T_s), T_s \in S(R)) \tag{8}$$