Computers and Electrical Engineering 36 (2010) 442–454

Contents lists available at ScienceDirect

Computers and Electrical Engineering

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

Model and analysis of path compression for mobile Ad Hoc networks

Xu Jia *, Li Qian-mu, Zhang Hong, Liu Feng-yu

College of Computer Science and Technology, Nanjing University of Science and Technology, Nanjing 210094, China

ARTICLE INFO

Article history:
Received 14 July 2008
Received in revised form 20 August 2009
Accepted 6 November 2009
Available online 24 December 2009

Keywords:
Communication technology
Ad Hoc networks
Path compression
Dynamic model

ABSTRACT

Path compression techniques are efficient on-demand routing optimizing techniques for mobile Ad Hoc networks. However, there is no efficient model for path compression techniques. This paper analyzed the principles and characteristics of path compression algorithms and proposed dynamic model which provided theoretical basis to improve or propose path compression algorithms. This model took the mobility and expansibility of Ad Hoc networks into account and was efficient to analyze or evaluate path compression algorithms. The quantitative relationship and probability expression for pivotal compression events were given based on the model. The simulation results of SHORT (self-healing and optimizing routing techniques) and PCA (path compression algorithm) show that it is a correct and efficient dynamic model for path compression. Finally, some suggestions and application scenarios about the model were proposed.

1. Introduction

Mobile multi-hop Ad Hoc networks are self-creating, self-organizing and self-administrating wireless networks without deploying any kind of infrastructure [1]. These characteristics make MANETs have a bright prospect in military, disaster recovery areas, commerce, education and any other applications without the support of infrastructure. However, the design of routing strategy in MANETs is a challenging work due to the movement, restricted energy and limited processing ability of nodes. The conventional routing protocols which need long-term stability topology and complicated calculation are difficult to be applied to MANETs.

Ad hoc networks need efficient routing protocols which can deal with the dynamic network topology without much overhead. At present, many Ad Hoc routing protocols have been proposed. According to the driven mode, these protocols can be divided into two categories: table-driven routing protocols and on-demand driven routing protocols. Route discovery strategy of table-driven routing protocol is originated from the traditional routing protocol which periodically exchange routing information between nodes, and each node must maintain an updated routing table to other nodes. However, high costs are needed to construct the routing tables with integrated routing information and to maintain the routing information. Therefore, table-driven routing protocols are unfit for those Ad Hoc networks with large scale or low traffic loads. The main idea of on-demand routing protocols is that the process of routing starts only when there are data to be sent. That is to say it is unnecessary to broadcast routing information periodically. Such mechanism releases occupation of network resources effectively. On-demand routing protocols have obvious advantages in scalability and effectiveness. Typical Ad Hoc on-demand routing protocols include AODV [2], DSR [3], TORA [4] etc.

The routing discovery mechanisms (using RREQ/RREP) of typical on-demand routing protocols will establish a shortest (with minimum hop counts) route. However, the mobility of nodes and the absence of global topology information make the path established by routing discovery mechanisms become no longer optimal after a period of time. Even if there are

* Corresponding author. Tel.: +86 13815861639.
E-mail address: xujia@mail.njust.edu.cn (X. Jia).

0045-7906/$ - see front matter Crown Copyright © 2009 Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.compeleceng.2009.11.002

shorter paths toward destination which are more reasonable and optimal in the current network, routing protocols cannot apperceive them. Routing protocols will retain the original path until the path broken, then the re-routing request initiated. But this is not expected because long paths need more network resources than of short paths, which will lead to poor routing performance. The confirmed disadvantages of long path are: (1) more bandwidth consumption, (2) more energy consumption; (3) increase end-to-end delay; (4) increase the number of routing requests; (5) reduce packet delivery ratio; (6) reduce survival time of routes (increase the probability of destructing the paths); (7) increase the probability of self-conflict phenomenon [5].

Path optimality and stability are important issues for routing protocols when stable paths are more reliable and offer better quality of service (minimal end-to-end delay). Path compression techniques can effectively solve the above problems. In fact, path compression techniques aim at developing a potential shorter path based on on-demand routing protocol. Related work [6–8] has proved that path compression techniques are effective method to reduce the consumption of resources and improve network performance.

In some occasion, path compression techniques try to find the most optimal path to optimize the original path generated by the routing discovery mechanism. Fig. 1a shows a path with eight hop counts (from source *A* to destination *I*) which was generated by routing discovery process. This path may be the shortest path or very close to the shortest path. For the mobility of nodes, this path might be transformed into the shape as shown in Fig. 1b after a period of time: node *J* which not belonged to the original path entered into the transmission range of node *A*, node *E* which belonged to the original path entered into the transmission range of node *J*, node *F* and node *H* entered into the transmission range of each other. Now the ideal path is shown in Fig. 1c, which has only five hop counts. Nevertheless, general routing protocols evaluate the availability of a path by the effectiveness of next hop. As long as the current path is valid, routing information will never be updated (even more optimal path existed). Path compression techniques were proposed to solve this problem.

In general terms, (n,k) short-cuts implies that n routing hops can be reduced to k hops, where $k < n$. When $k < 3$ (it is difficult to deal with the compressions when $k \geqslant 3$), path compressions are possible under two scenarios: (1) two nodes on the active route come close to each other giving rise to a $(n,1)$ short-cuts; (2) a node that is not on the active route comes closer two different nodes on the active route and form a shorter route. This gives rise to $(n,2)$ short-cuts.

In Fig. 2a, the original local path *A–B–C* has been compressed to *A–C*, which is termed as (2,1) short-cut; in Fig. 2b, the original local path *A–B–C–D* has been compressed to *A–E–D*, which is termed as (3,2) short-cut. If $k > 3$, the compression algorithm will become complicated and lead to instability with extra cost. So the current path compression techniques just consider $(n,1)$ short-cuts and $(n,2)$ short-cuts. In fact, $(n,1)$ short-cuts happened when two nodes which had belonged to the original path but not in one hop count entered into the transmission range of each other. $(n,2)$ short-cuts happened when one node which had not belonged to the original path entered into this path and connected two nodes that located on the original path but more than three hop counts between them. Some path compression algorithms [1,7] were designed according to such property.

This paper aims at the construction of a dynamic and efficient model for path compression techniques. The quantitative relationship and probability expression for pivotal compression events were also given based on the model. The contributions of our compression model are:

(1) make the setting of algorithm parameters more scientific;
(2) provide important reference performance analysis of algorithms;

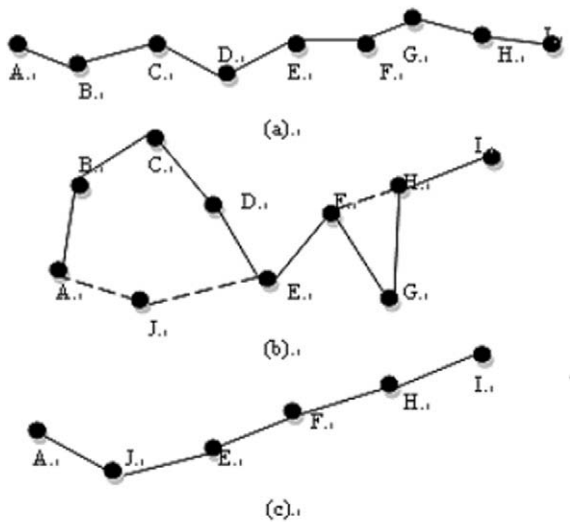

Fig. 1. An example of the path changes.