QoS-aware Fault-tolerant Routing in MANETs based on Segment-backup Paths

by

Ajay Agarwal

Department of Computer Science and Engineering

Submitted

in fulfillment of the requirements of the degree of

Doctor of Philosophy

to the

Indian Institute of Technology Delhi

MAY 2006

1. Mobile adhoc networks

Certificate

This is to certify that the thesis titled "**QoS-aware Fault-tolerant Routing in MANETs based on Segment-backup Paths**" submitted by Ajay Agarwal to the Indian Institute of Technology Delhi for the award of the degree of Doctor of Philosophy is a record of bonafide research work carried out by him under my supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted to any other university or institute for the award of any degree or diploma.

Bijendra N. Jain
Professor
Department of Computer Science and Engineering
Indian Institute of Technology Delhi
Hauz khas, New Delhi 110 016

To my family,
for their unwavering love and support

Acknowledgments

I would like to express my sincere gratitude to my thesis supervisor, Prof. Bijendra Nath Jain, for his guidance and encouragement during my research tenure at IIT Delhi. I am grateful to him for having a tremendous influence on my professional development. This thesis would not exist without his expert guidance, and inspiration. I would like to thank Prof. Jain for facilitating visits to conferences at Cambridge, UK and Singapore. These visits gave me opportunities to interact with other researchers working in the field. I am very grateful to CISCO, for funding my doctoral research. I would like to thank my standing review committee members, Professors Subhasis Banerjee, Sanjiva Prasad and H. M. Gupta for their encouragement and valuable suggestions. Special thanks to my fellow researchers Ash Mohammad, Vaishali Paithankar, Parag Chaudhuri, Subhajit Sanyal, Anup Gangwar, Basant Dwivedi, Uma Mudenagudi, and Ayesha Chaudhary for their help and encouragement during my research work. I would like to thank Rajesh ji, Negi ji and Kaushik ji for their help. I am deeply indebted to my family members for their help and patience. Thanks, Archana, for your help, care, and understanding throughout. I would like to thank all those people who helped me directly or indirectly in completing my research work at IIT Delhi.

Ajay Agarwal

Abstract

In the context of mobile ad hoc networks (MANETs), we consider the problem of identifying (a) an optimal primary path which satisfies the required QoS constraints, and (b) a set of alternate paths that may be used in case a link or a node on the primary path fails. The alternate paths are also required to satisfy the same set of QoS constraints as is the case with the primary path. In the thesis, we have proposed that the traffic be re-routed along a sub-path that by-passes a segment (portion) of the primary path that contains the failed link or node. The segments are determined based on (a) availability of alternate paths, and (b) so that QoS constraints are met. This flexibility in identifying the segments can also be used to ensure that the delay in switching traffic over to an alternate path, and the resulting packet loss, are bounded.

It is proved that for a given (a) source-destination pair of nodes in a network, and (b) any primary path between them, the nodes on the primary path can be divided into a collection of segments such that for each segment there exists an alternate path which completely by-passes the segment *if and only if* there exist two or more node-disjoint paths between the source and destination nodes. This implies that if there exists a solution consisting of a set of alternate backup paths *for a given primary path* then such a solution can always be found for *any* primary path.

We present a *centralized* algorithm to compute a primary path π_0 between a given pair of nodes and a corresponding set of *QoS-constrained* alternate paths each of which bypasses a segment of π_0. The set of such alternate paths is referred as a complete set of segment-backup paths. Such an algorithm may be used in case when the network topology is known a-priori. But, since the topology of a MANET is not fixed and therefore unknown a-priori, we have proposed a heuristic to identify a significant fraction of available paths between the source and destination nodes.

As the centralized algorithm is compute-intensive, we also propose a *distributed* DSR-like Segment-Backup Routing (DSBR) protocol. The protocol helps distribute computation over the nodes in the MANET and, in the process, it simultaneously discovers a primary path and the corresponding complete set of segment-backup paths each of which satisfies the QoS constraints viz., maximum permissible one way end-to-end delay, minimum required bandwidth, minimum required path reliability. Together, they satisfy maximum permissible one way switch-over delay. Suitable structures of routing tables are also developed to enable data packets to use *any* form of IP routing mechanism (viz. strict source routing, loose source routing, or otherwise).

To speed-up identification and establishment of a primary path and the corresponding complete set of segment-backup paths between a source S and destination D, we establish a result which takes advantage of an existing primary path and the corresponding complete set of segment-backup paths from an *intermediate* node to the same destination D.

Contents