UNIVERSITI PUTRA MALAYSIA

PERFORMANCE ENHANCEMENT OF ROUTING PROTOCOLS IN MOBILE WIRELESS AD-HOC NETWORKS USING FUZZY REASONING ALGORITHM

ESSAM FATHI NATSHEH

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By

ESSAM FATHI NATSHEH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

Especially dedicated to my parents ....

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: Associate Professor Adznan Jantan, PhD

Faculty: Engineering

The challenge in creating a routing protocol for ad-hoc networks is to design a single protocol that can adapt to the wide variety of conditions that can be present in any ad-hoc network environment. The routing protocol must perform efficiently in environments in which it suffers from high nodes mobility and many wireless transmission constraints. Because it is often impossible to know in advance what environment the protocol will find itself in, and because the environment can change unpredictably, the routing protocol must be able to adapt automatically. In this thesis, we use fuzzy reasoning algorithm (FRA) as a highly adaptive algorithm to achieve that goal. We will present the various application of that algorithm to ad-hoc routing protocols. Then, we will focus on four major applications that are the core of any ad-hoc routing protocol. These applications are: route lifetime estimation, local connectivity

management, nodes affinity management, and active queue management. In the first method, fuzzy reasoning is used to estimate the time the route can stay active in the routing table. In the second method, fuzzy reasoning is used to optimize the maximum time period that can transpire before the node broadcast the 'Hello' messages. Mapping the relationship between the signal strength fluctuation and links lifetime is presented in the third method. Finally, in the last method fuzzy reasoning is used for network congestion estimation and estimating the time to start dropping incoming packets. Extensive performance analysis via simulation proves the effectiveness of using the FRA to improve the accuracy of routing protocol parameters and hence the overall network performance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENAMBAHBAIKAN PERSEMBAHAN PROTOKOL LALUAN DALAM RANGKAIAN TANPA WAYAR MUDAH ALIH YANG TIDAK TETAP MENGGUNAKAN ALGORITMA PEMIKIRAN KESAMARAN

Oleh

ESSAM FATHI NATSHEH

Oktober 2006

Pengerusi: Profesor Madya Adznan Jantan, PhD

Fakulti: Kejuruteraan

Cabaran dalam mereka sesuatu protokol laluan untuk rangkaian sementara ialah merekabentuk satu protokol unggul yang dapat menyesuaikan diri dengan pelbagai situasi di dalam mana-mana rangkaian sementara. Protokol laluan ini harus cekap menangani permasalahan yang disebabkan oleh perpindahan nodus yang tinggi dan pelbagai halangan dalam penghantaran tanpa wayar. Oleh kerana untuk mengetahui secara terkehadapan situasi bagaimana protokol tersebut akan melalui adalah sukar dan juga situasi ini boleh berubah tanpa dapat diramal, protokol laluan ini harus boleh menyesuaikan diri secara automatik. Dalam tesis ini, kami menggunakan Algoritma Pemikiran Kesamaran (FRA) sebagai algoritma yang sangat sesuai untuk mencapai tujuan yang dinyatakan. Kami akan kemukakan pelbagai aplikasi algoritma tersebut untuk protokol laluan sementara. Kami juga akan memberi

tumpuan kepada empat aplikasi utama yang menjadi asas kepada mana-mana protokol laluan sementara. Aplikasi-aplikasi tersebut adalah anggaran jangkahayat perjalanan, pengurusan penyambungan dalaman, pengurusan keserupaan nodus dan pengurusan barisan aktif. Di dalam kaedah pertama, pemikiran kesamaran digunakan untuk menganggar masa yang diambil oleh perjalanan tersebut untuk berada dalam keadaan aktif didalam jadual perjalanan. Dalam kaedah kedua, pemikiran kesamaran digunakan untuk mengoptimakan semaksima masa yang boleh diketahui sebelum satu nodus menyiarkan pesanan “Hello”. Ilustrasi hubungan diantara perubahan kekuatan signal dan jangkahayat penyambungan telah dikemukakan dalam kaedah ketiga. Dalam kaedah yang terakhir, pemikiran kesamaran digunakan untuk penganggaran kesesakan rangkaian dan mengganggar masa permulaan untuk menjatuhkan peket-peket yang masuk. Analisa perlaksanaan secara meluas melalui simulasi membuktikan keberkesanan penggunaan FRA untuk memperbaiki ketepatan parameter protokol laluan dan seterusnya persembahan rangkaian secara keseluruhan.

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IN THE NAME OF ALLAH, THE BENEFICENT, THE MERCIFUL

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I certify that an Examination Committee has met on 20th of October 2006 to conduct the final examination of Essam Fathi Natsheh on his Doctor of Philosophy thesis entitled "Performance Enhancement of Routing Protocols in Mobile Wireless Ad-Hoc Networks using Fuzzy Reasoning Algorithm" in according with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

ESSAM FATHI NATSHEH

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AODV	Ad-hoc On-demand Distance Vector
ABR	Associatively Based Routing
ACK	Acknowledgment
AQM	Active Queue Management
ARED	Adaptive Random Early Detection
ART	Active Route Lifetime
BER	Bit Error Rate
COA	Centre of area
DSR	Dynamic Source Routing
DTTRR	Distance to Transmission Range Ratio
FCA	Fuzzy Connection Admission
FIS	Fuzzy Inference System
FRA	Fuzzy Reasoning Algorithm
GPS	Global Positioning System
HI	Hello Interval
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
LCM	Local Connectivity Management
LL	Link Lifetime
MAC	Media Access Control
MANET	Mobile Ad-hoc Networks
MF	Membership Function

NW	Normal Walk
PDF	Probability Density Function
QoS	Quality of Service
RED	Random Early Detection
RERR	Route Error
RF	Radio Frequency
RFC	Request for comments
RREP	Route Reply
RREQ	Route Request
RTO	Retransmission Timeout
RW	Random Walk
RWP	Random Waypoint
SentCtrlPkt	Sent Control Packets
SNR	Signal to Noise Ratio
TCP	Transmission Control Protocol
TORA	Temporally Ordered Routing Algorithm
TrPower	Transmission Power
TrRange	Transmission Range
TZRP	Two-Zone Routing Protocol
UDP	User Datagram Protocol
ZRP	Zone Routing Protocol

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

In the last few years, there has been a big interest in mobile wireless ad-hoc networks as they have enormous promise in military and commercial applications. A wireless ad-hoc network is a network without fixed infrastructure, contains mobile computing devices that use wireless transmission for direct communication for the nodes inside the transmission range and indirect communication (multi-hop technique) for the nodes outside the transmission range. Thus, the network nodes serve as routers and they are responsible for traffic routing and topology management. To achieve that, the nodes use routing protocols designed to take into account the challenges of ad-hoc environment and make optimal attempt to find the routes to the destinations.

A variety of ad-hoc routing protocols have been proposed in the recent past. These protocols have tried to optimize the routing functions to deal with challenges of ad-hoc networks. The major challenges that the ad-hoc routing protocols face are: nodes mobility that generate frequent links breaks, bandwidth constraints due radio band limitation, frequent packets collisions due the broadcast

nature of radio channels, limited nodes lifetime due to their batteries lifetime constraints, and limited topology information due to limited transmission range of wireless devices.

Due to these issues of ad-hoc network environment, the ad-hoc routing protocols must be highly adaptive and be able to provide a certain level of uncertainty. As a well recognized decision making technique, fuzzy reasoning offers a natural way of representing and analyzing problems with uncertainty and imprecision. Fuzzy reasoning is a suitable way to be applied in the mobile ad-hoc network routing decision.

Fuzzy reasoning was originally created as a mathematical model of human thought. It is said that fuzzy reasoning is able to capture the "vagueness" and "inexactness" of the concepts that we use for analyzing. In the past decade, conventional computer networks have been the emerging area of success in applying fuzzy reasoning. The application of fuzzy reasoning for routing protocols allows us to specify the relationship between the protocols performance metrics and their optimization functions using "if…then…" type of linguistic rules. A fuzzy reasoning algorithm (FRA) would be able to translate or interpolate these rules into a nonlinear mapping between performance metrics and routing functions for routing protocols.