UNIVERSITI PUTRA MALAYSIA

A MATRIX USAGE FOR LOAD BALANCING IN SHORTEST PATH ROUTING

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A MATRIX USAGE FOR LOAD BALANCING IN SHORTEST PATH ROUTING

By

NOR MUSLIZA MUSTAFA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfillment of the Requirements for the Degree of Master of Science

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DEDICATION

Dedicated to my parents,

to my hubby,

to my kids,

and to all my brothers and sisters.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfillment of the requirements for the degree of Master of Science

**A MATRIX USAGE FOR LOAD BALANCING
IN SHORTEST PATH ROUTING**

By

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February 2009

Chair : Associate Professor Mohamed Othman, PhD

Faculty : Computer Science and Information Technology

The Open Shortest Path First (OSPF) protocol is a hierarchical interior gateway protocol (IGP) for routing in Internet Protocol. Traffic flows routed along shortest path and splits the load equally at nodes where a number of outgoing links on the shortest paths to the same destination IP address. Network operator defines shortest paths based on a link weights value assigned to each link in the network. The OSPF link weight-setting problem seeks a set of link weights to optimize a cost function and network performance, typically associated with a network congestion measure. This research highlight the importance of managing network resource and avoiding congested point in the current widely deployed shortest path routing.

The previous Evenly Balancing Method (EBM) and Re-Improved Balancing Method (R-IBM) used demand matrix, which requires constant monitoring of routers with high time executions in the optimization process. The problems are to find another matrix that can replace or minimize the usage of demand matrix with low time executions process. A new proposed Matrix Usage Method (MUM) is developed. MUM selects the shortest path routing in order to provide a balancing load and optimized the usage of link in the network. The simulation results show that the routing performance of the new proposed method MUM is better than the routing performance of the previous Evenly Balancing Methods (EBM) and Re-Improved Balancing Method (R-IBM) due to providing counting selection technique in the shortest path routing. MUM times executions are also improved comparing with the previous work.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

MATRIX PENGGUNAAN UNTUK KAEDAH PENGIMBANGAN BEBAN DI DALAM PENGHALAAN LALUAN TERPENDEK

Oleh

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Pengerusi: Profesor Madya Mohamed Othman, PhD

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Protokol OSPF merupakan protokol hirark i dalaman untuk penghalaan di dalam protokol Internet. Pengaliran trafik dilaksanakan di atas laluan terpendek dan membahagikan beban sama rata kepada nod, di mana beberapa pautan keluar berada di atas laluan terpendek ke destinasi IP yang sama. Operator rangkaian mengenalpasti laluan terpendek melalui nilai pautan pemberat yang ditetapkan kepada setiap pautan di dalam rangkaian. Masalah penetapan pautan pemberat OSPF ialah mencari set pautan pemberat untuk mengoptimumkan fungsi kos dan prestasi rangkaian, yang pada kebiasaannya melibatkan pengukuran kesesakan rangkaian. Penyelidikan ini menekankan kepentingan menguruskan sumber rangkaian dan penghindaran pautan sesak di dalam penghalaan laluan terpendek yang ada.

Di dalam penyelidikan sebelum ini kaedah pengimbangan sama (EBM) dan kaedah pengimbangan yang diperbaiki (R-IBM) telah menggunakan matrik permintaan yang memerlukan pengawasan yang tetap ke atas router dengan pengarangan jumlah masa yang tinggi di dalam proses pengoptimuman. Masalahnya ialah untuk mencari matrik lain yang boleh menggantikan atau mengurangkan penggunaan matrik permintaan dengan proses pengarangan jumlah masa yang rendah. Satu kaedah baru yang

dinamakan sebagai Kaedah Matrix Penggunaan (MUM) dibangunkan. MUM memilih penghalaan laluan terpendek di dalam menyediakan keseimbangan beban dan mengoptimumkan penggunaan pautan di dalam rangkaian. Keputusan simulasi menunjukkan bahawa prestasi penghalaan bagi kaedah MUM adalah lebih baik daripada prestasi penghalaan kaedah sebelum ini iaitu Kaedah Pengimbangan Sama (EBM) dan Kaedah Pengimbangan Yang Diperbaiki (R-IBM) dengan menyediakan teknik pengiraan pilihan di dalam penghalaan laluan terpendek. Dari aspek pengarangan jumlah masa MUM juga diperbaiki berbanding penyelidikan yang terdahulu.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been properly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

NOR MUSLIZA MUSTAFA

Date: 17 July 2009

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Successful?

LIST OF ABBREVIATIONS

AS	Autonomous System
BGP	Border Gateway Protocol
EBM	Evenly Balancing Method
ECMP	Equal Cost Multiple Path
EGP	Exterior Gateway Protocol
IETF	Internet Engineering Task Force
IGP	Interior Gateway Protocols
IP	Internet Protocol
IS-IS	Intermediate System-Intermediate System
ISP	Internet Service Provider
LCDM	Local Congestion Detection Method
MUM	Matrix Usage Method
OSPF	Open Shortest Path First
QoS	Quality of Service
RIP	Routing Information Protocol
R-IBM	Re-using avoided Congested Links – Improved Balancing Method
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol

CHAPTER 1

INTRODUCTION

1.1 Background

The Internet is a collection of routing domains into many routing domains called Autonomous Systems (ASes) that interact to control the delivery of Internet Protocol (IP) traffic. As the amount and criticality of data being carried on IP networks grows, managing network resources to ensure reliable and acceptable performance becomes increasingly important. Open Shortest Path First (OSPF) is the most commonly used intra-domain Internet routing protocol (Fortz and Thorup, 2004) (Retvari and Cinkler, 2004). Routers are such protocol to exchange link weights and construct a complete view of the topology inside the AS. Then, each router computes shortest paths (path length in the sum of link weights) and creates a table that controls the forwarding of each IP packet to the next hop in its route. OSPF provides shortest path first routing, simple load balancing by Equal Cost Multi Path (ECMP), which the traffic is split equally between equal cost path and resources to manipulate routing through setting the administrative link weights. In the case of multiple shortest paths, OSPF will use load balancing and split the traffic flow equally over several shortest paths (Moy, 1998). Dijkstra's shortest path computation algorithm is widely employed in OSPF implementations.

Normally, size of the network increases OSPF implementations can become unbalanced due to processing overload caused by extremely flooding and/or by regularly Dijkstra executions during periods of network instability. OSPF implementations also apply various mechanisms to help scalability. Network operators assign link weights. The lower the link weight, the greater the chance that traffic will be routed on that link. Cisco is the major router vendor that assigns OSPF link weights as inverse of the link capacity (Cisco, 2006).

In general, the current shortest path routing suffers a problem of arising congested links (Fortz *et al*., 2002b) (Fortz and Thorup, 2004). It is due to the extremely usage of the shortest paths, while the other paths are unutilized. Many ISP's have a huge infrastructure based on routers running shortest path protocols like OSPF (Retvari and Cinkler, 2004). Congested links could appear if they have lower link weights because all the traffic from any source to any destination will follow the shortest paths, while still other links or paths unutilized (Fortz and Thorup, 2002a). OSPF is known to be a simple routing protocol in two senses. Firstly, its routing is completely determined by one weight for each link. Secondly, it provides simple load balancing by splitting traffic loads almost equally among equal cost paths. (Retvari and Cinkler, 2004).

Importance in traffic-engineering mechanisms has prompted router vendors to define various extensions in presenting a protocol to enable traffic-engineering deployment. In general, traffic-engineering issues have been studied under QoS routing. Traffic demand patterns clearly play a role in determining the frequency of traffic-engineering related link state advertisements. If the frequency of such advertisements is very low, the information available in every routers link state database can become very musty. It has been shown that musty information may limit the benefits of richer network connectivity. It has also been suggested that in order to exploit on solid network topologies, link state updates should be more standard and as a result, there is a need for techniques for dealing the extreme link state traffic. The first work was done by (Fortz and Thorup, 2000a) (Fortz and Thorup, 2000b) and published in (Fortz and Thorup, 2004). They argued that a smart OSPF link weights setting could improve its efficiency and will distribute traffic over network links efficiently. They also proved that OSPF link weights setting is a NP-hard (Non-deterministic Polynomial) complete problem and proposed a taboo search with evenly balancing method to set the link weights optimally. Many optimization algorithm, utilize the same framework of Fortz were developed (Ericson *et al*., 2002) (Buriol *et al*., 2002) (Buriol *et al*., 2005) to optimize OSPF link weights in genetic algorithms. In (Roughan *et al*., 2003) combined traffic matrix estimation with traffic-engineering of OSPF in order to estimates the traffic matrix and then optimizes OSPF link weights using the framework described in (Fortz *et al*., 2002b).

1.2 Problem Statement

This research is dutiful to solve the following problems:

- Traffic Demand Matrix Problem: Previous works such as (Fortz and Thorup, 2000a)(Fortz and Thorup, 2000b)(Fortz and Thorup, 2002a)(Fortz *et al*., 2002b)(Ericsson *et al*., 2002)(Buriol *et al.*, 2005)(Roughan *et al*., 2003)(Fortz and Thorup, 2004)(Villamizar, 2002)(Michael and Nemeth, 2002)(Miguel *et al.*, 2005)(Abrahamson *et al.*, 2002)(Ashwin, 2004)(Ashwin *et al.*, 2005)(Miguel *et al*., 2005)(Wing *et al*., 2005)(Makarem, 2007) using the same traffic demand matrix in their experiment. The problem is to find another matrix to optimize the link weights instead of using demand matrix. It is because the way to measure the demand matrix is a difficult task and need a constant monitoring of routers in a certain time.
- Time Executions Problem: Previous balancing methods those optimize link weights (Fortz and Thorup, 2000a) (Fortz and Thorup, 2000b) (Fortz and Thorup, 2004) (Ericsson *et al.*, 2002) (Buriol *et al.*, 2002) (Buriol *et al.*, 2005) (Makarem, 2007) suffer from a problem to minimize the time executions which is needed for the optimization process. This problem deals with the research of designing the link weights optimization methods efficiently.

1.3 Research Objectives

The objective of this research is:

- To improve the routing performance of load balancing in the traditional routing communications without any adaptations to the routing protocols or the forwarding mechanisms of the operational network.

1.4 Research Scope

This research will focus on the performance optimization of operational networks such as a company, a university or service provider. These types of operational networks are known as Autonomous Systems (ASes) that interact to control and deliver IP traffic. The performance optimization will be considered on reducing traffic congestions and managing network resources efficiently. Reducing traffic congestions in ASes that operates under the intra-domain routing protocol OSPF will also reduce the traffic congestions in the entire Internet, hence improving its performance. The performance optimization of OSPF networks will be limited to its link weights. This limitation is due to the need of maintaining traditional routing policy while dealing with the rapid changes of the new technologies in the network fields that provides dynamic Quality of Service (QoS).

1.5 Research Contributions

The contributions of this research are:

This research solved the problems to find another alternative matrix to optimize the link weights instead of using demand matrix and reducing the time executions in optimization process to achieve the optimal/near optimal routing performance. Solving this problem helps in analyzing and understands the technique of counting and selecting routing path. New Matrix Usage Method (MUM) that supports a counting selection technique gives a new direction to improve OSPF routing. The routing paths are based on the link weights of operational network. MUM method aims to maintain the current widely deployed traditional routing, meanwhile profitable the capabilities of counting selection.

1.6 Thesis Organization

This thesis is organized as follows. Chapter 2 gives a detailed background about the previous work. Chapter 3 details the research methodology. Chapter 4 presents our new proposed balancing method that applies counting selection technique and the improvement achieved for the time that is needed for the optimization process. The conclusion and the future works will be found in Chapter 5.