TRAFFIC BALANCING METHOD IN SHORTEST PATH ROUTING

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By

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

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DEDICATION

***Dedicated to my parents*,**

***to my wife*,**

***to my kids*,**

and to all my brothers and sisters.

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

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Chairman: Associate Professor Mohamed Othman, PhD

Faculty: Computer Science and Information Technology

Open Shortest Path First (OSPF) is the most commonly used intra-domain routing protocol. OSPF routes traffic flows along shortest paths and splits the load evenly at nodes where several outgoing links are on the shortest paths to the same destination. Shortest paths are defined based on a weight value assigned to each link in the network. OSPF routing suffers from un-utilizing network resources, and hence appearance of congested links. Congestion appears in OSPF routing due to the excessive usage of shortest paths where still other links with higher weight values are unutilized.

Many load balancing approaches were proposed to avoid congestion and increase network utilization. One of these approaches argued that optimizing link weights will improve shortest path routing performance, thus no changing needed in underlying infrastructure. Weight optimization approach neither deal with the issue of load splitting, nor the tradeoff relation between exploiting network resources and avoiding congested points. Increasing balanced links may lead to a usage of congested links. On the other hand, avoiding congested links may lead to un-utilizing some un-congested links.

This research has two main aims. The first aim is to study the tradeoff relation between utilizing network links and avoiding congested links. The second aim is to provide an unequal load splitting in the current widely deployed shortest path routing. Unequal load splitting that provided in this research is conducted without changing the underlying routing policy and without changing the forwarding mechanism. In context of the first research aim, a previous evenly balancing method is improved by solving two problems. The first problem is Re-using Congested Links (RCL). The second problem is Un-Balancing some available Links (UBL). Solving these two problems will give a wide view about the tradeoff relation between utilizing network links and avoiding congested links. In context of the second research aim, a new proposed Selective Balancing Method (SBM) is developed. SBM selects the routing paths in order to provide unequal load splitting.

Experimental results show that avoiding congested links is more efficient than exploiting too many links from a source towards a destination. In other words, solving RCL problem increases routing efficiency more than solving UBL problem. The results also show that the routing performance of the new proposed method SBM is better than the routing performance of the previous evenly balancing methods due to providing unequal load splitting in the shortest path routing. SBM robustness and execution time are also improved comparing with the previous work.

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

KAEDAH PENGIMBANGAN TRAFIK DALAM PENGHALAAN LALUAN TERPENDEK

Oleh

MAKAREM MOHAMED ABDULQADER BAMATRAF

Mac 2007

Pengerusi: **Profesor Madya Mohamed Othman, PhD**

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Protokol OSPF merupakan protokol penghalaan antara-domain yang biasa digunakan. OSPF menghalakan perjalanan trafik di atas laluan terpendek dan akan membahagikan beban dengan sama rata kepada setiap nod, di mana beberapa pautan keluar ke destinasi yang sama berada di atas laluan terpendek tersebut. Laluan terpendek di interpretasikan berdasarkan nilai pemberat yang telah ditetapkan untuk setiap pautan dalam rangkaian. Penghalaan OSPF mengalami masalah pembaziran sumber rangkaian yang seterusnya mengakibatkan kesesakan pautan. Kesesakan dalam OSPF berlaku disebabkan oleh penggunaan berlebihan dalam laluan terpendek sedangkan masih banyak pautan lain yang tinggi pemberat tidak digunakan sepenuhnya.

Terdapat banyak kaedah pengimbangan beban telah diusulkan untuk mengelakkan kesesakkan dan meningkatkan penggunaan rangkaian. Salah satu pendekatan yang diambil adalah dengan mengoptimumkan penggunaan beban pautan untuk meningkatkan prestasi penghalaan, laluan terpendek diperluluan tanpa menjejaskan infrastruktur sedia ada. Kaedah pengoptimuman pemberat tidak melibatkan isu pembahagian beban dan timbal balik antara eksploitasi sumber rangkaian dengan

penghindaran titik sesak. Pertambahan pautan seimbang boleh menyebabkan penggunaan pautan sesak semakin bertambah hingga menyebabkan berlakunya pembaziran pautan tidak sesak yang tidak digunakan.

Penyelidikan ini mengsasarkan dua tujuan utama. Tujuan pertama adalah untuk mengkaji hubungan timbal balik antara pertambahan penggunaan pautan dengan penghindaran pautan sesak. Tujuan kedua adalah untuk menyokong penggunaan penghalaan laluan terpendek. Kajian literatur menerangkan tentang ketaksamaan pembahagian beban yang akan disokong oleh penyelidikan tanpa mengubah polisi asas penghalaan dan mekanisma hadapan dalam konteks halatuju pertama, kaedah pengimbangan sebelum ini ditingkatkan dengan menyelesaikan dua masalah iaitu penggunaan semula pautan sesak (RCL) dan ketidakseimbangan pautan sedia ada (UBL). Penyelesaian dua masalah ini memberikan gambaran menyeluruh terhadap hubungan timbal balik. Sementara itu, dalam halatuju kedua, satu kaedah baru yang dinamakan sebagai pengimbangan pilihan (SBM) telah dibangunkan untuk memilih laluan penghalaan berdasarkan beberapa kriteria kesesakan yang menyokong ketidakseimbangan pembahagian beban.

Keputusan simulasi menunjukkan bahawa masalah RCL mengurangkan ketepatan penghalaan lebih daripada masalah UBL. Dalam erti kata lain, penghindaran laluan sesak lebih efisien berbanding jika mengeksploitasi terlalu banyak pautan untuk menuju destinasi yang sama. Keputusan juga menunjukkan bahawa prestasi penghalaan bagi kaedah SBM yang baru diperkenalkan berupaya mengatasi prestasi penghalaan kaedah sebelum ini. Penghalaan SBM adalah lebih baik berbanding kaedah sebelum ini dari aspek kegagalan rangkaian dan pengarangan jumlah masa yang diperlukan untuk mendapatkan nilai pemberat yang optimum.

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I certify that an Examination Committee has met on 26 / 3 /2007 to conduct the final examination of Makarem Mohamed Abdulqader Bamatraf on his Doctor of Philosophy entitled "Traffic Balancing Method in Shortest Path Routing" in accordance 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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Date: 17 July 2007

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.

MAKAREM MOHAMED BAMATRAF

Date: 18 June 2007

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AS	Autonomous System
ATM	Asynchronous Transfer Mode
BGP	Border Gateway Protocol
EBM	Evenly Balancing Method
ECMP	Equal Cost Multiple Path
EGP	Exterior Gateway Protocol
GCDM	Global Congestion Detection Method
IBM	Improved Balancing Method
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
MIB	Management Information Bases
MPLS	Multiple Protocol Label Switching
NP	Non-deterministic Polynomial
OSPF	Open Shortest Path First
OSPF-OMP	Open Shortest Path First – Optimized Multi-Path
QoS	Quality of Service
RCL	Re-using avoided Congested Links
R-IBM	Re-using avoided Congested Links - Improved Balancing Method

RIP	Routing Information Protocol
SBM	Selective Balancing Method
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
UBL	Un-Balancing available Links
U-IBM	Un-Balancing available Links - Improved Balancing Method
UR-IBM	UBL and RCL Improved Balancing Method