IMPACTS OF WIDE AREA NETWORK BANDWIDTH CAPACITY ON THE WEB ACCESS PERFORMANCE IN A PROXY-BASED ENVIRONMENT

A thesis submitted to the Faculty of Information Technology in full fulfillment of the requirements for the degree
Master of Science(Information Technology)
Universiti Utara Malaysia

By

Abdul Hadi Kamel bin Abdullah

JABATAN HAL EHWAL AKADEMIK
(DEPARTMENT OF ACADEMIC AFFAIRS)
UNIVERSITI UTARA MALAYSIA

PERAKUAN KERJA/TESIS
(Certification of Thesis Work)

Kami, yang bertandatangan, memperakukan bahawa
(We, the undersigned, certify that)

ABDUL HADI KAMEL ABDULLAH

calon untuk Ijazah
(candidate for the degree of) ***SARJANA SAINS (TEKNOLOGI MAKLUMAT)***

telah mengemukakan tesis/disertasinya yang bertajuk
(has presented his/her thesis work of the following title)

IMPACTS OF WIDE AREA NETWORK BANDWIDTH CAPACITY ON THE WEB ACCESS PERFORMANCE IN A PROXY-BASED ENVIRONMENT

seperti yang tercatat di muka surat tajuk dan kulit tesis/disertasi
(as it appears on the title page and front cover of thesis work)

bahawa tesis/disertasi tersebut boleh diterima dari segi bentuk serta kandungan, dan liputan bidang ilmu yang memuaskan, sebagaimana yang ditunjukkan oleh calon dalam ujian lisan yang diadakan pada : **23 Julai 2006**

(that the thesis/dissertation is acceptable in form and content, and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through an oral examination held on

Pengerusi Viva *(Chairman for Viva)*	:	Prof. Madya Dr. Hjh. Norshuhada Shiratuddin	Tandatangan: *(Signature)*	
Pemeriksa Luar *(External Examiner)*	:	Prof. Dr. Md. Yazid Mohd. Saman	Tandatangan: *(Signature)*	
Pemeriksa Dalaman *(Internal Examiner)*	:	Encik Azman Ta'a	Tandatangan: *(Signature)*	
Penyelia Utama *(Principal Supervisor)*	:	Encik Ahmad Suki Che Mohamed Arif	Tandatangan: *(Signature)*	
Dekan, Fakulti Teknologi Maklumat *(Dean, Faculty of Information Technology)*	:	Prof. Madya Dr. Hj. Zulkhairi Md. Dahalin	Tandatangan: *(Signature)*	

Tarikh
(Date) : **23 JULAI 2006**

PERMISSION TO USE

In presenting this thesis in full fulfillment of the requirements for a post graduate degree from Universiti Utara Malaysia, I agree that the University Library may make it freely available for inspection. I further agree that permission for copying of this thesis in any manner, in whole or in part, for scholarly purposes may be granted by my supervisor(s) or, in their absence, by the Dean of the Graduate School. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to Universiti Utara Malaysia for any scholarly use which may be made of any material from my thesis.

Requests for permission to copy or to make other use of materials in this thesis, in whole or in part should be addressed to:

Dean of Faculty of Information Technology
Universiti Utara Malaysia
06010 UUM Sintok
Kedah Darul Aman.

ABSTRAK

Secara amnya, dengan menambahkah kapasiti lebarjalur talian WAN yang menyambungkan LAN di sesebuah organisasi ke Internet akan mengurangkan masa respon bagi capaian Web. Penyelidikan kami adalah bagi mengenalpasti sama ada dengan menambahkan kapasiti lebar jalur talian WAN dalam sesebuah organizasi akan turut memberikan kesan yang sama jika pengguna-pengguna Web tidak disambungkan terus ke Internet tetapi melalui pelayan proxy bercache. Penyelidikan kami memfokuskan kepada mengenalpasti kesan-kesan pengurangan dan penambahan lebarjalur ke atas purata 'latency' dalam capaian Web yang terdiri daripada tiga komponen iaitu masa penyambungan TCP, masa bagi mendapatkan aksara yang pertama selepas penyambungan dibuat dan masa muat turun bagi sesuatu objek Web. Kajian kami menggunakan kaedah eksperimen di mana kami telah menjalankan sebilangan eksperimen berasaskan jejak yang dijalankan dalam persekitaran rangkaian yang terpisah bagi mensimulasikan capaian Web pengguna-pengguna melalui sebuah pelayan proxy dalam sebuah organisasi melalui talian WAN. Hasil eksperimen menunjukkan peratusan pengurangan purata 'latency' capaian ke Web yang disebabkan oleh 'Web caching' menyusut dengan penambahan kapasiti lebar jalur sambungan WAN. Hasil eksperimen juga menunjukkan keupayaan pelayan proxy bagi mengurangkan masa 'latency' bagi mencapai objek Web menyusut dengan lebih cepat sekiranya pelayan proxy berkenaan mempunyai ruang ingatan yang lebih kecil.

ABSTRACT

Generally, by adding bandwidth capacity on Wide Area Network links, which connect organizations' Local Area Network to the Internet will ease the slow response of users Web access. Our study is to find out whether adding bandwidth capacity on organizations Wide Area Network links will give the same result if the users' web access in the organizations is not made directly to the remote Web sever but via a caching proxy server. Our study focuses on identifying the effects of WAN bandwidth capacity on the average latency of Web access, which is composed of three components namely TCP connection establishment time, time taken to get the first byte of the requested Web object after the connection to the server has been established and the downloading time of the Web object. Our investigation utilized experimental approach, where we conducted several trace-driven experiments in isolated network environment to simulate users web access through a single proxy server in an organization across Wide Area Network link. Our results indicate that the percentage of reduction of average web access latency due to web caching diminishes with the increment of the Wide Area Network bandwidth capacity. Another interesting finding from our results is the degree of Web access latency reduction diminishes more rapidly if the caching proxy server has limited amount of memory.

ACKNOWLEDGMENTS

Firstly, I give thanks to Almighty Allah, the beneficent, the merciful for guiding me to this stage of my life.

I am indebted to a large number of people in completing this thesis, all of whom have contributed in one way or the other to the successful of completion of my Master Degree program in Universiti Utara Malaysia. First I would like to thank my previous supervisor Mr. Muhammad Shakirin Hj. Shaari and the current supervisor Mr. Ahmad Suki b Che Mohamed Arif for their guidance, valuable suggestions and promptness in reviewing my research work.

I would also like to thank the coordinators for the post-graduates studies at the Information Technology Faculty of Universiti Utara Malaysia for their continuous helps and encouragement. I am also deeply indebted to Mr. Khalil and Mr. Faris from Pusat Komputer Universiti Utara Malaysia for their relentless willingness to help me at different stages of my research. Mr. Khalil for giving me permission to use UUM proxy server log files in my study. Mr. Faris for assisting me in collecting the Web proxy log files entries throughout the data collection period of my research.

A special and highly appreciation to Universiti Teknologi MARA for sponsoring my studies and to Fakulti Teknologi Maklumat of Universiti Utara Malaysia for the facilities provided to carry out my research and Sekolah Siswazah for providing me research grant for buying equipment required for my research.

I would also like to express my highly appreciation to my family especially my beloved wife, Rafizah, my daughters Nani and Fatimah, my son Ikmal for their incredible support and patience.

May Allah gives continuous rewards to all of you. Amin.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 The Growth of the Internet

The Internet evolved from the initial ARPANET network in 1969, which was developed by the Advanced Research Project Agency (ARPA) of the U.S Department of Defense. Its main objective of the development was to allow networked computers to communicate transparently across multiple, linked packet networks. In its initial stage, the ARPANET only linked a number of four scientific and academic research networks across the United States. Since then the Internet is growing continuously at exponential rates with more and more networks from various types of organizations have been attached to it forming the world largest network. In terms of method for transferring data, the Internet uses TCP/IP protocols suite that comprises of several networking protocols developed for delivering various types of information on the network. The popularity of the Internet grows more rapidly with the major breakthrough of the World Wide Web by Tim Berners-Lee's in 1991. By the end of the year 1991, the Internet has linked some 5,000 networks in over three dozens countries, serving over 700,000 host computers used by over 4,000,000 people.

According to Petrazzini and Kibati (1999) the Internet has grown from a small, closed, text-based computer of few thousand scientific and government users in the early 1980s to around 43 million Internet hosts in some 58,000 separate but interconnected networks supporting an estimated 150 million users in early 1999. A

The contents of the thesis is for internal user only

Carson, M. & Santay, D. (2003). NIST Net: a Linux-based network emulation tool, *SIGCOMM Comput. Commun. Review*, 33(3): pp. 111-126.

Cohen, E., & Kaplan, H. (2000). Prefetching the means for document transfer: A new approach for reducing Web latency. Proceedings IEEE INFOCOM, 2, (pp 854-863), Tel-Aviv, Israel.

Comer, D. E (1997). *Computer Networks and Internets*. New Jersey : Prentice-Hall.

Davison, B.D. (1999). A survey of proxy cache evaluation techniques. *Proceedings of the Fourth International Web Caching Workshop*, (pp 67-77), San Diego, California. Retrieved March 24, 2003 from http://www.cse.lehigh.edu/~brian/pubs/1999/wcw/wcw99survey.pdf

Davison, B.D. (2001). A Web caching primer. *IEEE Internet Computing*, 5(4), 38-45.

Dyson, P. (1999). *Dictionary of Networking (3rd ed.)*. Alameda, CA: Sybex.

Fan, L., Cao, P., Almeida, J., & Broder, A. Z. (2000). Summary cache: a scalable wide-area web cache sharing protocol. *IEEE/ ACM Trans. Network*, 8(3), 281-293.

Feldmann, A., Caceres, R., Douglis, F., Glass, G., & Rabinovich, M. (1999). Performance of Web Proxy Caching in Heterogeneous Bandwidth Environments. *Proceedings of the IEEE INFOCOM '99 conference*, (pp 107-116), New York, NY. Retrieved March 19, 2003 from http://citeseer.nj.nec.com/article/feldmann99performance.html

Floyd, S., & Paxson, V. (2001). Difficulties in Simulating the Internet, *IEEE/ACM Transactions on Networking*, 9(4), 392-403. Retrieved March 24, 2003 from http://doi.acm.org/10.1145/504640.504642

Floyd, S., & Kohler, E. (2003). Internet research needs better models, SIGCOMM Comput. Commun. Rev., 33(1), 29-34. Retrieved October 17, 2006 from http://doi.acm.org/10.1145/774763.774767

Forouzan, B. A (2004). *Data Communication and Networking*. Singapore : McGraw-Hill.

Habib, M. & Abrams, M. (2000). Analysis of Sources of Latency in Downloading Web Pages. *Proceedings of WebNet 2000. San Antonio*, Texas. Retrieved March 24, 2003 from http://citeseer.ist.psu.edu/habib00analysis.html

Hada, H., Chinen, K., Yamaguchi, S. & Oie, Y. (1999). Behavior of WWW Proxy Servers in Low Bandwidth Conditions, *Proceedings of the 4th International Web Caching Workshop*. San Diego, California. Retrieved March 19, 2003 from http:// citeseer.nj.nec.com/91353.html

Haugdahl, J.S., (2000). *Network analysis and troubleshooting*, Canada : Addison-Wesley

Hu, X., & Heywood, A.N.Z. (2005). Understanding the Performance of Cooperative Web Caching Systems. *Proceeding of the CNSR 2005*, (pp. 183-188), Halifax, Canada. Retrieved July 11, 2005, from http://doi.ieeecomputersociety.org/10.1109/CNSR.2005.61

IPJava, G. P. (2001). Iptraf – An IP Network Monitor, Retrieved July 12, 2005, from http://iptraf.seul.org/

Johnson, T. (1997). Stuff Tom's Written. Retrieved March 24, 2003 from http://teryx.bobdbob.com/~protius/software/

Kiracofe, D. (2002). Transparent Proxy with Linux and Squid mini-HOWTO Transparent Proxy to a Remote Box. Retrieved March 24, 2003 from http://en.tldp.org/HOWTO/mini/TransparentProxy-6.html

Krishnamurthy, B., Zhang, Y., Wills, C. E., & Vishwanath, K. (2003). Design, implementation, and evaluation of a client characterization driven Web server, *Proceedings of the twelfth international conference on World Wide Web*, (pp. 138-147), Budapest, Hungary. Retrieved July 11, 2005 from http://doi.acm.org/10.1145/775152.775172

Kroeger, T.M., Long, D.D.E., & Mogul, J.C. (1997). Exploring the Bounds of Web Latency Reduction from Caching and Prefetching. *In Proceedings of the 1997 Usenix Symposium on Internet Technologies and Systems*, Monterey, CA. Retrieved March 19, 2003 from http:// citeseer.nj.nec.com/kroeger97exploring.html

Kurose, J.F., Ross, K. W. (2001). *Computer Networikng; A Top-Down Approach Featuring the Internet*, Boston, Massachuset, USA: Addison Wesly.

Liu, B., & Fox, E.A. (1998). Web} Traffic Latency: Characteristics and Implications, *Journal of Universal Computer Science*, 4(9), 763-778. Retrieved March 24, 2003 from http:// citeseer.nj.nec.com/liu98Web.html

Liu, B., Abdulla, G., Johnson, T., & Fox, E. (1998). Web Response Time and Proxy Caching. *Proceedings of WebNet 98*,Orlando, Florida. Retrieved March 19, 2003 from http://citeseer.ist.psu.edu/article/liu98web.html

Loon, T.S., & Bhargavan, V. (1997). Alleviating the Latency and Bandwidth Problems in {WWW} Browsing, *In Proceedings of the 1997 Usenix Symposium on Internet Technologies and Systems*, Monterey, CA. Retrieved March 24, 2003 from http://citeseer.nj.nec.com/loon97alleviating.html

Luotonen, A., & Altis, K. (1994). World-Wide Web proxies. *Computer Networks and ISDN Systems*, 27(2), 147-154. Retrieved March 19, 2003, from http://citeseer.nj.nec.com/luotonen94worldwide.html

Maltzahn, C., Richardson, K. J., & Grunwald, D. (1997). Performance issues of enterprise level Web proxies. *Proceedings of the 1997 ACM SIGMETRICS international conference on Measurement and modeling of computer systems*, (pp 13-23), Seattle, Washington .Retrieved March 19, 2003 from http://doi.acm.org/10.1145/258612.258668

Maltzahn, C., Richardson, K. J., & Grunwald, D. (1999). Reducing the Disk I/O of Web Proxy Server Caches. *Proceeding of the 1999 USENIX Ann. Technical Conf*, (pp 225-238), Monterey, CA.

Mogul, J.C (1995). The case for persistent-connection HTTP, *Proceedings of the conference on Applications, technologies, architectures, and protocols for computer communication*, (pp 299-313), Cambridge, Massachusetts, United States. Retrieved August 9, 2004 from http://doi.acm.org/10.1145/217382.217465

Nametka, W. (1999). Network performance and capacity planning: Techniques for e-business world. Retrieved March 24, 2003 from IBM United States Web site: http://www-1.ibm.com/services/its/us/source/nametka.pdf

Netfilter (n.d). netfilter/iptables - Home. Retrieved March 24, 2003 from http://www.netfilter.org

Nichols, J., & Claypool, M. (2004). The effects of latency on online madden NFL football, Proceedings of the 14th international workshop on network and operating systems support for digital audio and video, (pp. 146-151), Cork, Ireland. Retrieved July 11, 2005 from http://doi.acm.org/10.1145/1005847.1005879

Nichols, J., Claypool, M., Kinicki, R., & Li, M. (2004). Measurements of the congestion responsiveness of Windows Streaming Media, *Proceedings of the 14th international workshop on Network and operating systems support for digital audio and video*, (pp. 94-99), Cork, Ireland.

Nielsen, H.F.,Gettys, J., Baird-Smith, A., Prud'hommeaux, E., Lie, H.W.,& Lilley, C. (1997). Network performance effects of HTTP/1.1, CSS1, and PNG. *Proceeding of the ACM SIGCOMM '97 conference on Applications, technologies, architectures, and protocols for computer communication*, (pp 155-166), Cannes, France. Retrieved March 19, 2003,from http://doi.acm.org/10.1145/263105.263157

NIST (2002). NIST Net installation instructions. Retrieved March 24, 2003 from http://snad.ncsl.nist.gov/itg/nistnet/install.htm

Padmanabhan, V.N., & Mogul, J.C. (1995). Improving HTTP latency, *Computer Networks and ISDN Systems*, 28(1-2), 25-35. Retrieved March 19, 2003, from http://www.cs.berkeley.edu/~padmanab/papers/www_fall94.ps

Petrazzini, B. & Kibati, M. (1999). The Internet in Developing Countries. Communication of the ACM, 42(6), 31-36.

Raunak, M. S., Shenoy, P., Goyal, P., & Ramamritham, K. (2000). Implications of proxy caching for provisioning networks and servers. *Proceedings of the 2000 ACM SIGMETRICS international conference on Measurement and modeling of computer systems*, (pp 67-77), Santa Clara, California. Retrieved March 19, 2003 from http://doi.acm.org/10.1145/339331.339357

Rivest, R. L. (1992). RFC 1321 – The MD5 Message-digest Algorithm. Retrieved July 12, 2005, from http://www.faqs.org/rfcs/rfc1321.html

Rosu, M., & Rosu, D. (2002). An evaluation of TCP splice benefits in web proxy server, *Proceedings of the eleventh international conference on World Wide Web*, (pp. 13-24). Honolulu, Hawaii, USA.

Rousskov, A., & Soloviev, V. (1998). On Performance of Caching Proxies (extended abstract), *ACM SIGMETRICS Performance Evaluation Review*, 26(1), 272-273. Retrieved March 24, 2003 from http://doi.acm.org/10.1145/277858.277946

Rousskov, A. (1997). Index of -~rousskov-research-cache-sanitar. Retrieved March 24, 2003 from http://www.cs.ndsu.nodak.edu/~rousskov/research/cache/sanitar/

Rutkowski, A.M. (2000). Internet Trends. Retrieved August 11, 2004, from http://www.ngi.org/trends/trends-200002/tsld001.htm

Saari, M.S., Mahmuddin, M., & Abdullah, A.H.K. (2002). Implication of Internet Worms Attack on the performance of Web access in proxy-based environment : A case study of NIMDA Worm attack, *Proceedings of TEMPO 2002*, Universiti Utara Malaysia, Sintok, Malaysia.

Tanenbaum, A. S. (1996). *Computer Networks (3rd ed.)*. New Jersey : Prentice-Hall.

Wang, J. (1999). A survey of Web caching schemes for the Internet. *ACM SIGCOMM Computer Communication review*, 29(5), 36-46. Retrieved March 19, 2003, from http://doi.acm.org/10.1145/505696.505701.

Wessels, D. (2004). Wessel, D. (2001), Squid Frequently Asked Questions, Retrieved July 11, 2005, from http://www.squid-cache.org/Doc/FAQ/

Wooster, R. P. & Abrams, M. (1997). Proxy caching that estimates page load delays. *Proceedings of the Sixth International World Wide Web Conference*, pages 325-334, Santa Clara, CA.

Zhang, X. (2000). Xiaohui Zhang. *Cachability of Web objects*. Technical Report BUCS-2000-019, Boston University Computer Science, 2000.