

**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 menambahkan 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 organisasi 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

PERMISSION TO USE	i
ABSTRACT (BAHASA MALAYSIA)	ii
ABSTRACT (ENGLISH)	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	ix
LIST OF FIGURES	x
CHAPTER 1 : INTRODUCTION	
1.1 The Growth of the Internet	1
1.2 Requirement for Higher Network Bandwidth of WAN Links	2
1.3 Using Proxy Server to Improve Web Access Performance	4
1.4 Motivation and Approach for the Study	
1.4.1 Motivation for the study	6
1.4.2 Approach for the study	8
1.5 Research Questions	10
1.6 Objectives of the Study	11
1.7 Theoretical Framework	12
1.8 Scope of the Study	19
1.9 Contributions of the Study	20
1.10 Thesis Outline	21
CHAPTER 2: BACKGROUND AND RELATED WORKS	
2.1 Brief history of the Internet and World Wide Web	23

2.2 Overview of Wide Area Network Links	26
2.3 World Wide Web Caching Proxies	28
2.4 Benefits of Web Caching	30
2.5 Methods Used in Web Access Performance Evaluation	32
2.6 Related Works on Web Access Performance Evaluation	35
 CHAPTER 3: RESEARCH METHODOLOGY	
3.1 Overview	40
3.2 Trace-driven Experiment Approach	41
3.3 Description of the Experiments	42
3.4 Assumptions and Limitations of the Experiments	44
3.5 Hardware and Software Tools Used for the Experiments	
3.5.1 Web client computer	47
3.5.2 Web proxy server computer	48
3.5.3 Local router	49
3.5.4 Web server computers	49
3.5.5 Local Area Networks	50
3.5.6 Edge router	51
3.5.7 WAN link	52
3.6 URL List and Web Objects Preparation for the Experiments	
3.6.1 Source of the URL inputs	53
3.6.2 URLs transformation using MD5 encoding	55
3.6.3 Web objects preparation for the experiments	59
3.7 Experimental Design	
3.7.1 Web access test-bed	61

3.7.2 Redirecting HTTP request to the proxy server	62
3.7.3 Varying bandwidth capacity on the emulated WAN link	63
3.7.4 Varying user workload intensity level on the test-bed	64
3.7.5 Varying memory capacity on the proxy server	64
3.7.6 Automating the configuration HTTP traffic generator and designated WAN link bandwidth settings	65
3.7.7 Precautionary measures during the experiments	66
3.7.8 Parameters measured during experiments	67

CHAPTER 4: EXPERIMENT RESULTS AND ANALYSIS

4.1 Overview	69
4.2 Data Analysis Process	69
4.3 Analysis of Data for Average Latency for Different Bandwidth Capacity of WAN Link	70

CHAPTER 5: DISCUSSIONS OF RESULTS

5.1 Overview	73
5.2 Web Access latency Under Different WAN Bandwidth Capacity	73
5.3 Impacts of Web Proxy Caching on the Web Access Latency	75
5.4 Percentage of Latency Reduction Due to Web Caching	76
5.5 Impacts Web Access Latency Components	
5.5.1 TCP connection establishment time	78
5.5.2 Time to get the first byte of a Web object	81
5.5.3 Downloading time	83
5.6 Percentage of Time Taken for Each Component of Web Access Latency	84
5.7 The Impact of Physical Memory Capacity of the Web Proxy Server	89
5.8 Comparison of the Results with the Previous Study	91

CHAPTER 6: CONCLUSIONS AND FUTURE WORKS	
6.1 Conclusions	94
6.2 Future Works	95
REFERENCES	97
APPENDICES	103

LIST OF TABLES

Table 1.1 :	Descriptions of events in a proxy-based Web access environment	17
Table 1.2 :	Descriptions of events in a direct Web access environment	18
Table 3.1 :	Summary of the trace-driven experiments for the study	44
Table 3.2 :	Example of transformation of variable length URLs into MD5 encoded string	57
Table 3.3 :	Distribution of Web access load on the computers representing remote Web server	58
Table 3.4 :	Characteristics of transformed URLs trace used in the experiments	59
Table 4.1 :	Results from the analysis of data for low user workload intensity level (10 concurrent processes)	71
Table 4.2 :	Results from the analysis of data for high user workload intensity level (50 concurrent processes)	72

LIST OF FIGURES

Figure 1.1 :	Typical delays in a proxy-based environment	14
Figure 1.2 :	Time values of events for a Web access in proxy-based Web access environments	16
Figure 1.3 :	Time values of events for a Web access in a direct Web access environment without a Web proxy server	18
Figure 2.1 :	Packets exchanges in HTTP protocol	25
Figure 2.2 :	Typical set-up of a proxy-based Web access environment	28
Figure 3.1 :	Steps involved in the trace-driven experiments on the test-bed	42
Figure 3.2 :	Web access test-bed set-up	62
Figure 5.1 :	Average Web access latency per request for low users workload level (10 concurrent users)	74
Figure 5.2 :	Average Web access latency per request for high users workload level (50 concurrent users)	75
Figure 5.3 :	Percentage of average latency reduction against WAN bandwidth capacity	77
Figure 5.4.1 :	Average connection establishment time per request for low user workload intensity level (10 concurrent users)	80
Figure 5.4.2 :	Average connection establishment time per request for high user workload intensity level (50 concurrent users)	80
Figure 5.4.3 :	Average time to get the first byte per request for low user workload intensity level (10 concurrent users)	82
Figure 5.4.4 :	Average time to get the first byte per request for high user workload intensity level (50 concurrent users)	82
Figure 5.4.5 :	Average downloading time per request for low user workload intensity level (10 concurrent users)	83
Figure 5.4.6 :	Average downloading time per request for high user workload intensity level (50 concurrent users)	84

Figure 5.5.1 :	The Web access latency components ratio for low user workload intensity level with Web proxy server memory capacity = 512 MB	86
Figure 5.5.2 :	The Web access latency components ratio for low user workload intensity level with Web proxy server memory capacity = 256 MB	87
Figure 5.5.3 :	The Web access latency components ratio for low user workload intensity level without a Web proxy server	87
Figure 5.5.4 :	The Web access latency components ratio for high user workload intensity level with Web proxy server memory capacity = 512 MB	88
Figure 5.5.5 :	The Web access latency components ratio for high user workload intensity level with Web proxy server memory capacity = 256 MB	88
Figure 5.5.6 :	The Web access latency components ratio for high user workload intensity level without a Web proxy server	89
Figure 5.6 :	Average Latency ratio between a proxy-based and direct Web access	92

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). NIS1 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., Willis, 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 Networkng; A Top-Down Approach Featuring the Internet*. Boston, Massachuset, USA: Addison Wesley.
- 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(1), 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.