

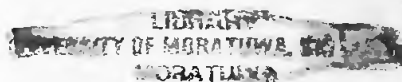
8

LB/DON/22/06

DYNAMIC BANDWIDTH NEGOTIATION SYSTEM FOR LAN/WAN

THESIS PRESENTED BY
W.G.S. BANDULA

SUPERVISED BY
P.G.V. DIAS



This thesis was submitted to the Department of Computer Science and Engineering of the
University of Moratuwa – Sri Lanka
In partial fulfillment of the requirements for the
Degree of Master of Science

004 "05"
004 (043)

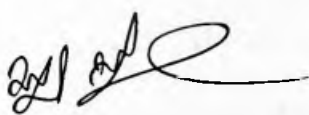


Department of Computer Science and Engineering
University of Moratuwa
Sri Lanka
December 2005

85976

85976

The work presented in this dissertation has not been submitted for the fulfilment of any other degree



.....
W.G.S. Bandula
Candidate

UOM Verified Signature

.....
P.G.V. Dias
Supervisor



TO MY PARENTS...

Abstract

The Internet is a critical infrastructure today, in both developed and developing countries. Most of developed countries have reached large percentage of their population with high bandwidth internet connections. They have gigabit links at organisations and megabit connections even at homes. Now, the focus is terabit speed connections. Much current researches in developed countries focus this era of the technology.

This thesis is concentrated on the Internet connections used at educational institutes. The Internet is heavily used by students, researches and the academic staff for academic purposes. Further, most of the sites they access are distributed around the world. The amount of local content is very little in developing countries. Therefore, unlike developed countries that have lot of internal traffic, developing countries have the problem of scarcity of international bandwidth.

The cost of International bandwidth is unbearable for the economies in developing countries. There is less than 10 Mbps bandwidth available of the entire University system in Sri Lanka. Many of the organisations are relied on dialup links or ADSL connections which are about 56~128 kbps. Only a few organisations have dedicated 128kbps ~ 2Mbps links.

Many of organisations have multiple Internet links (e.g., departments in the same University) to the same local network. These departments are willing to share their spare bandwidth with others, provided that they will receive other's excess bandwidth in their needy time, if available. Bandwidth as a whole can be better utilized by such sharing.

Our research addressed the above issues and came up with a system for dynamic bandwidth sharing among co-operative organisations. The system is developed as a plug-in for the open source Web proxy software, *Squid*. It consists of:

1. Bandwidth Monitoring System
2. Inter-Proxy Bandwidth Negotiation Protocol
3. Module for Bandwidth Granting on demand
4. Module for Optimal User Redirection via multiple uplinks

The Bandwidth Monitoring System in each proxy server continuously monitors the local bandwidth link usage. If the local link is under-utilized it announces the available excess bandwidth to its neighbours. If the monitoring system detects that the local proxy is running out of bandwidth it checks neighbours announces to retrieve excess bandwidth from them. Inter-Proxy Bandwidth Negotiation Protocol is used to negotiate bandwidth among proxy servers. When the system decides particular bandwidth donor it uses the Bandwidth Granting Module to permit the bandwidth requester through the donor's link. User Redirection Module optimizes the local user redirection via multiple uplinks at the bandwidth requester's end for better utilization of both links.

Currently a prototype of the system is deployed for the two Internet links available at the University of Moratuwa. It proves that the collective bandwidth sharing improves the bandwidth utilization as a whole among co-operative organisations.



Acknowledgement

This dissertation could not be possible without the support I got from Dr. Gihan Dias. He helped me not only as the supervisor of my research, but also with many other supports to make sure proper progress of the research. During the countless discussions I had with him, I always felt that I got in to the correct track.

At the same time, I should not forget the Senior Academic staff of Department of Computer Science & Engineering, University of Moratuwa. Especially, Dr. Sanath Jayasena, Mr. Shantha Fernando and Ms. Vishaka Nanayakkara who took the trouble of spending their valuable time in evaluating progress of my research project. Their constructive comments encouraged me all the time. Dr. Ashok Peiris, as the head of the Department helped me in all the administrative work related to my M.Sc. and processed every document without any delay. He always pushed me towards the success of the program.

Prof. Dileeka Dias provided me a valuable support through out my research project not only as a member of evaluation panel but also Director, Dialog Research Lab allowing me to test and deploy my research project on their live 2M Internet link.

I cannot forget the external supervisor, Dr. Nimal Ratnayake who took the trouble of going through the entire thesis within give short period time.

Further, I must thank my colleague Chamara Disanayake, who worked in collaboration with me throughout research project. Technical but friendly and fun full discussions we had, made me relax all the time. At the end, we could complete a really useful system to the benefit of students and staff in the University of Moratuwa.

I thank K. Rajeevan, the System Engineer, Department of CSE for all of his constructive feedback and support in setting up and configuring the system. He did not delay any of the system support I requested.

Additionally I would like to thank my other research colleagues Janaka Wijesena, Rohana Dasanayake and Kutila Gunasekara who took the trouble of my continuous disturbs in asking questions and requesting feedback on my research work. They were not hesitated to do the system test at any time I requested.

This research was financially supported by Asian Development Bank (ADB). It was a great initiative for me to start my research Master.

I thank my beloved wife Pradeepa providing continued support and encouragement during my research work. She was not only my beloved wife but also an invaluable research partner.

I dedicate this thesis to my parents who have dedicated their entire life for my education.

Index

- 1. Introduction 1
 - 1.1 Background 1
 - 1.2 Motivation 2
 - 1.3 Requirements..... 3
 - 1.4 Problems..... 3
 - 1.5 Other Approaches..... 4
 - 1.5.1 Traffic Controller (tc)..... 4
 - 1.5.2 Internet Cache Protocols (ICP) 5
 - 1.6 Proxy Sever 6
 - 1.7 Squid Proxy 6
 - 1.8 Proposed Solution 7
 - 1.8.1 System Overview 7
 - 1.8.2 System's Logic..... 7
 - 1.8.3 System Implementation..... 8
- 2. Existing system 10
 - 2.1 Delay Pools in Squid 10
 - 2.1.1 Token Bucket Algorithm..... 10
 - 2.1.2 Token Bucket Hierarchy in Delay Pools..... 11
 - 2.1.3 Initialization of Delay Pools..... 12
 - 2.1.4 Delay Pool Stages..... 13
 - 2.1.5 Drawbacks of Delay Pools in Squid..... 14
 - 2.2 Dynamic Delay Pools..... 14
 - 2.2.1 Bandwidth allocation within the pool 15
 - 2.2.2 Transferring bandwidth among delay pools..... 16
 - 2.3 What is missing? 16
- 3. Better Bandwidth Utilization with Improved Dynamic Delay Pools..... 18
 - 3.1 Upgrading to Newer Squid Version..... 18
 - 3.2 Problem of Bandwidth Transfer among Delay Pools..... 18
 - 3.3 Improving Bandwidth Management within a Single Pool 19
 - 3.3.1 Introduction of Common Individual Restore Value..... 19
 - 3.3.2 Individual Minimum Limit Removal 20
 - 3.3.3 Poor Bandwidth Utilization at Off-peak Time..... 22
 - 3.4 Support for the User Initiated Bandwidth Management System..... 24
- 4. Bandwidth Monitoring 25
 - 4.1 The Importance of Bandwidth Monitoring in My Research 25
 - 4.2 Existing Bandwidth Monitoring Tools..... 25
 - 4.2.1 Multi-Router Traffic Graph (MRTG) 26
 - 4.2.2 Webalizer for Squid Log Analysis 26
 - 4.3 Own Approaches 27
 - 4.3.1 Squid Log Analyser..... 27
 - 4.3.2 Bandwidth Monitoring using delayBytesIn() Function 29
 - 4.4 Analysing Results..... 30
- 5. Inter-Proxy Bandwidth Negotiation 32
 - 5.1 Necessity of Inter-Proxy Bandwidth Communication 32
 - 5.2 Overall System 32
 - 5.2.1 Understanding the Functionality 32
 - 5.2.2 Overall Implementation..... 33
 - 5.3 Local Bandwidth Detection of the Proxy..... 35
 - 5.4 Bandwidth Usage Pattern Recording 36

5.4.1 Recent Usage Pattern	37
5.4.2 Five Minute Summary for 7 Days of the Week	38
5.5 Decision Making System	38
5.6 Inter-Proxy Communication.....	39
5.6.1 Message Handling System	40
5.6.2 Inter-Proxy Bandwidth Negotiation Protocol	41
5.7 Bandwidth Receiver End: Redirecting Local Traffic.....	43
5.8 Bandwidth Donor End: Allocation for the Requesters	45
5.9 System Deployment at University of Moratuwa.....	45
5.9.1 Local Bandwidth Detection Subsystem	45
5.9.2 Bandwidth Monitoring & Announcing	46
5.9.3 Announcement Analyzer.....	46
5.9.4 Squid Peer Status Updater.....	46
5.9.5 Local User Redirector	46
6. Results	49
6.1 Best Approach for Local Bandwidth Monitoring	49
6.2 Selection of Threshold Values for User Redirection Algorithm.....	52
6.3 Effectiveness of Inter-Proxy Bandwidth Negotiation System	55
7. Conclusion.....	58
7.1 Challenges	58
7.2 Contributions.....	59
7.3 Future Directions.....	59
7.3.1 Inter-Proxy Communication via Multicast.....	59
7.3.2 Dynamise Token Bucket Algorithm at Kernel Level.....	60
7.3.3 Identification of Bandwidth Sharing Policies	60
7.3.4 Advanced Bandwidth Reservation.....	60
7.3.5 Tuning the System by Varying the Parameters.....	60
7.3.6 Solve the Problem of User Swapping	60
References	62
Appendices	64

Index of Pictures & Tables

Fig 1-01: Centralized Bandwidth at LEARN	2
Fig 1-02: System Model	3
Seg 1-01: tc Syntax	4
Fig 1-03: Role of a Proxy	6
Fig 1-04: System Overview	7
Fig 1-05: Unutilized Bandwidth	7
Fig 1-06: System's Logic	8
Fig 1-07: Flowchart of the Entire System	8
Fig 2-01: Concept of Delay Pool	10
Fig 2-02: Delay Pool's Hierarchy in Squid	11
Seg 2-01: Delay Pool Parameters Setting	12
Fig 2-03: Delay Pool Initialization	13
Fig 2-04: Different Delay pool Status	13
Fig 2-05: Bandwidth Allocation within the Delay Pool	15
Fig 2-06: Bandwidth Transfer among Delay Pools	16
Fig 2-07: Possibilities of bandwidth transfer	17
Fig 3-01: Convergence of Individual Restore Values of a Delay Pool	19
Fig 3-02: Unfair Individual Restore Values in Original Dynamic Delay Pools	19
Fig 3-03: Common Restore Value for a Delay Pool	20
Tbl 3-01: Restore value calculation with time	21
Seg 3-01: Function to Set Restore Value of Delay Pools	24
Fig 4-01: MRTG Link Analysis – University of Moratuwa (1st February 2005 at 20:16)	26
Fig 4-02: Sample Result from Webalizer – University of Moratuwa, May 2004	26
Seg 4-01: Squid Log Analyzer Exception for Local Traffic	28
Fig 4-03: Initial High Download Speed Drops to a Very Low Value Soon	28
Fig 4-04: Speed Variation with the time in a single file download	29
Seg 4-02: Bandwidth Monitoring through Delay Pools	30
Fig 4-05: Results derived from Squid Log Analyzer	31
Fig 5-01: How Inter-Proxy Bandwidth Negotiation Works	33
Fig 5-02: Implementation of Inter-Proxy Bandwidth Negotiation	34
Fig 5-03: Flexibility of Local Bandwidth Detection System	36
Seg 5-01: Recent Usage Pattern Structure	37
Seg 5-02: Upgrading Upper Level of Usage Patter Records	38
Seg 5-03: Five Minutes Backup Structure per Day	38
Fig 5-04: Algorithm used in Decision Making System	39
Fig 5-05: Algorithm for Bandwidth Negotiation	40
Fig 5-06: Inter-Proxy Bandwidth Negotiation Protocol	41
Fig 5-08: Redirection of Local Traffic via Multiple Uplinks	44
Seg 5-04: Five Minutes Backup Structure per Day	44
Fig 5-09: Flowchart of the Entire System	45
Fig 5-10: User Redirection Algorithm	47
Fig 6-01: Link Usage as calculated by MRTG and Excess_Bytes	49
Fig 6-02: Link Usage as calculated by MRTG & delayBytesIn	50
Fig 6-03: Link Usage as calculated by MRTG	51
Fig 6-04: Link Usage as calculated by MRTG & Direct Interface Readings	51
Tbl 6-01: Abbreviations for the Threshold Values	52
Fig 6-05: Link Usage vs. Lower Threshold of the Local Link	52
Fig 6-06: Link Usage vs. Upper Threshold of the Local Link	53
Fig 6-07: Link Usage vs. Lower Threshold of the Neighbour Link	54



Fig 6-08: Link Usage vs. Lower Threshold of the Neighbour Link 54

Tbl 6-02: Suitable Threshold Values 54

Fig 6-09: Deploying the IPBNS in the Production 55

Fig 6-10: Using Neighbour's Bandwidth without Total Increment 55

Fig 6-11: Improper Bandwidth Distribution among Uplinks..... 56

Fig 6-12: Optimal Bandwidth Usage Resulted by IPBNS 56

Fig 6-13: MRTG Monthly Report of Link Status 57