# Characterisation of End-to-End Performance for Web Based File Server Repositories

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Thesis submitted for the degree of

**MASTER'S OF ENGINEERING SCIENCE**

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AUSTRALIA

JANUARY 2001

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# Abstract


The Internet has evolved dramatically in the past few years as result of developments in internetworking/telecommunications technologies and increasing market demand for interactive services. While increasing service diversity is noticeable through steady competition for developing and delivering multimedia content, the Internet infrastructure as a whole has evolved in a rapid and almost "organic" fashion, resulting in an enormous mesh of hosts, networks and network peering points – a complex and fault susceptible environment. In addition, the lack of Quality of Service (QoS) standards and the lack of consensus on what is an adequate QoS level has led to an atypical situation where customers are serviced in a best-effort basis, without clear guarantees of effective performance.

In the face of these performance issues and the assortment of application service level requirements, several research initiatives have gained attention in the last few years. The main initiatives currently being debated are:

- Backbone improvements: bandwidth maximisation, development of new resource management/measurement techniques and tools, Mbone (Multicast Backbone), etc;
- Protocol improvements: IPV6, RSVP, Tag Switch, Jumbo-frames, TCP for high performance networks, routing protocols, etc;
- Data compression techniques: development of new compression methods for encapsulating video, audio and images over IP;
- New access technologies: Fibre wavelength re-use via DWDM (Dense Wavelength Division Multiplexing), Digital Subscriber Line (xDSL), Hybrid Fibre Coax (HFC) platforms, Local Multipoint Distribution Service (LMDS) systems, Multichannel Multipoint Distribution Service (MMDS) systems and high bandwidth satellite access;

- Economic drivers: new mechanisms for charging Internet traffic due to the inefficiency of traditional PSTN charging methods for measuring Internet usage and unfairness of peering agreements.

This report investigates the behaviour of TCP bulk file transfer application sessions in a broadband access environment. The focus is on the development of an end-to-end throughput measurement tool for evaluating the effects of *both* internetworking topology *and* application server traffic demand *over* throughput for a broadband user while downloading files from remote Web based file server repositories. In addition, the decision to carry out this research was influenced by three other reasons:

- Lack of standards for diagnosing, evaluating and correcting performance problems in a particular network;
- TCP packets are responsible for 90 to 95 percent of all Internet traffic [15];
- The importance of file downloading has increased together with the development of new compression formats because multimedia content such as compressed music, compressed video and general data can be widely found on the Web. Furthermore, NAPSTER[1] and other collaborative download environments have increased the popularity and demand for downloading files among a community of Internet users [9,10,11]. The traffic impact of NAPSTER has been such that some academic and commercial organisations are now prohibiting its use [12,13].

In terms of Internet analysis modelling, this research introduces some concepts for evaluating network behaviour: a path instability parameter ($\varepsilon$) for analysing different TCP connections; a minimum RTT delay and a minimum typical path for estimating path characteristics between a client and application servers.

The main findings of this research are: a strong correlation was observed between throughput performance and traffic demand in *both* the Application Server *and* interconnecting networks; some cyclical throughput behaviour suggesting a *high* influence of the US backbone on throughput performance for download sessions originating from Application Servers located outside Australia; throughput performance depends not only on technical drivers *but also* on economic drivers such as the inter-network pricing regime; for some downloading sites, low throughput performance seems to be related to a higher number of satellite links within interconnecting networks; finally, in spite of having a connectionless network layer, the Internet environment has a high path stability, i.e., it is predominantly connection-oriented. The latter confirms research carried our by Paxson, Lebovitz et al & Chinoy, where path changes affect less than 1% of Internet connections [41,45,46].

[1] See http://www.napster.com

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# Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the university library, being available for loan and photocopying.

**SIGNED** _______ **DATE** 23.01.01

# Acknowledgments

Firstly, I praise *God* for giving me health, tranquillity, patience and determination to challenge my limits during this great life experience.

This research project was carried out with the assistance of a Scholarship provided by my company, *Research and Development Centre for Information Processing and Automation* (CPDIA). I wish to express my deep appreciation *not only* for the financial support *but also* for the confidence and responsibility placed in me. Sincere appreciation is due to a number of professionals for making this period in Australia possible: *Prof. Edgard A. Romanato, Prof. Katsuyoshi Kurata, Prof. Osório Chagas Meirelles, Mr. Soji Iura, Mr. Aiser C. Cordeiro, Mr. Oswaldo Ken-Ichi Furuzawa* and *Mr. Edson Hayashi.*

I am grateful to my supervisor, *Prof. Reginald P. Coutts* for helping me improve my research skills, by stimulating my independent thinking and, primarily, for making sure I pursued my ideas.

I would like to express my special gratitude to *Dr. Sergey Nesterov* for his professionalism and guidance during the development of the experimental analysis of this project. Undoubtedly, without his fruitful discussions and his talent in software programming, this project would not have been so challenging and rewarding.

*Mr. David Klemitz* must be acknowledged for his encouragement, enthusiasm, criticisms, suggestions and mainly for his friendship during this academic experience.

I am also very thankful to all *Centre for Telecommunications Information Networking* (CTIN) staff, for providing a pleasant and welcoming research environment. Some people, however, deserve a special reference: *Mrs. Hilde Crook* for her professional

conduct, kindness and helpfulness; And, *Ms. Collete Snowden*, for her assistance in proofreading the final version of this thesis.

In addition, I am indebted to several professionals from *the University of Adelaide*. My sincere gratitude extends to three key people: *Prof. Ken Sarkies*, who was my first contact at the University and who has always demonstrated a welcoming and supportive attitude towards overcoming barriers faced; *Dr. Nigel Bean* for suggestions to improve the end-to-end delay performance analysis; And, *Prof. Lang White* for his relevant technical contributions for enhancing the ultimate development process.

Finally, the completion of this thesis is a victory for a person who has always been an example of life, dedication, determination and honesty. My extreme admiration goes to my *Mum* for all she has provided to me as a *Mum, friend* and *educator*.

# List of Publications

## Conference Publication:

Manoel Eduardo Mascarenhas da Veiga Alves, Reginald Paul Coutts & Sergey Nesterov, **"International Conference on Performance and QoS of Next Generation Networking - P&Q Net2000"**, November 27-30, 2000, Nagoya, Japan

# List of Abbreviations

## Acronym

| | |
|---|---|
| AAL5 | ATM Adaptation Layer 5 |
| AARNET | Australian Academic Research NETwork |
| ACK | ACKnowledgment flag |
| ADSL | Asymmetric Digital Subscriber Line |
| AS | Autonomous System |
| ATM | Asynchronous Transfer Mode |
| BDP | Bandwidth-Delay Product |
| BER | Bit Error Rate |
| BGP | Border Gateway Protocol |
| BSP | Backbone Service Providers |
| CERN | European Centre for Nuclear Research |
| CRC | Cyclic Redundancy Check |
| DARPA | Defense Advanced Research Projects Agency |
| DF | Don't Fragment bit |
| DNS | Domain Name System |
| DWDM | Dense Wavelength Division Multiplexing |
| EGP | Exterior Gateway Protocol |
| EndT | End Time |
| ESP | Encapsulating Security Payload |
| FDDI | Fibre Distributed Data Interface |

| | |
|---|---|
| FEC | Forward Error Control |
| FIFO | First In First Out |
| FIN | FINish flag |
| FTP | File Transfer Protocol |
| FTTB | Fibre To The Building |
| FTTH | Fibre To The Home |
| GEO | Geo-synchronous satellites |
| GIF | Graphics Interchange Format |
| GPS | Global Positioning System |
| HEC | Header Error Control |
| HFC | Hybrid Fibre Coax |
| HIPPI | High Performance Parallel Interface |
| HTTP | Hyper Text Transfer Protocol |
| ICMP | Internet Control Message Protocol |
| ID | Identification |
| IETF | Internet Engineering Task Force |
| IGP | Interior Gateway Protocol |
| IP | Internet Protocol |
| IPMP | Internet Protocol Measurement Protocol |
| IRR | Internet Routing Registry |
| IPv4 | Internet Protocol version 4 |
| IPv6 | Internet Protocol – version 6 |
| ISP | Internet Service Providers |
| JPEG | Joint Photograph Experts Group |
| LEO | Low Earth Orbit satellites |
| LFN | Long Fat Networks |

| | |
|---|---|
| LMDS | Local Multipoint Distribution Service |
| MEO | Medium Earth Orbit satellites |
| MMDS | Multichannel Multipoint Distribution Service |
| MPEG | Motion Picture Experts Group |
| MP3 | MPEG 1 Layer 3 |
| MSS | Maximum Segment Size |
| MTU | Maximum Transmission Unit |
| NFS | Network File System |
| NIC | Network Interface Cards |
| NNTP | Network News Transfer Protocol |
| NPD | Network Probe Daemon |
| NSP | Network Service Provider |
| NTP | Network Time Protocol |
| OSI | Open Systems Interconnection Reference Model |
| OSPF | Open Shortest Path First |
| OW | One-Way delay |
| PAWS | Protection Against Wrapped Sequence numbers |
| PERL | Practical Extraction and Report Language |
| PoP | Point of Presence |
| PMTUD | Path Maximum Transmission Unit Discovery |
| PSTN | Public Switch Telephone Network |
| QoS | Quality of Service |
| RAM | Real Audio Metafile |
| RSVP | Resource reSerVation Protocol |
| RST | ReSeT flag |
| RTT | Round Trip Time |

| | |
|---|---|
| SACK | Selective ACKnowledgment |
| SAA | Single Administrative Authority |
| SBF | Standard Benchmark File |
| SLA | Service Level Agreement |
| SNMP | Simple Network Management Protocol |
| SMTP | Simple Mail Transfer Protocol |
| StartT | Start Time |
| SYN | SYNchronise sequence numbers flag |
| TCB | TCP Control Block |
| TCP | Transmission Control Protocol |
| TTL | Time To Live |
| UDP | User Datagram Protocol |
| URL | Uniform Resource Locator |
| VCI | Virtual Channel Identifier |
| VDSL | Very high speed Digital Subscriber Line |
| VPI | Virtual Path Identifier |
| xDSL | Digital Subscriber Line |
| ZIP | A compression format |
| WAN | Wide Area Network |
| WWW | World Wide Web |

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***In memory of my Father –***
***whose enthusiasm, spontaneity and passion***
***for life will always be alive***