



**SIMULATION-BASED PERFORMANCE COMPARISON
OF TCP OVER IPV6 AND IPV4**

**A thesis submitted to the Faculty of Information Technology in
partial fulfillment of the requirement for the degree
Master of Science (Information Technology)
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By

ADIB HABBAL

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ABSTRACT

Internet Protocol ver-4 (IPv4) has been used for long times ago, but the great growth of the Internet and its change in drastic way over time makes IPv4 face many problems. The main one is the lack in address space, not to forget issues such as mobility and security. To meet requirements that didn't exist in IPv4, IP version 6 (IPv6) was designed. TCP protocol is as fundamental as IP protocol in the TCP/IP Protocol Suite. TCP adds some mechanisms to overcome unreliability and connectionless IP functionalities so can guarantee delivery the messages. In this project, we investigated the impact of using IPv6 on the behavior of TCP by comparing the performance of TCP over IPv6 and IPv4. TCP Reno (one of TCP flavors) is used in the comparison; NS-2 and OMNeT++ are tools used to perform the simulation experiments. During the course of simulation, throughput and delay (measured RTT) of TCP over IPv6 and IPv4 have been studied, and two different type of traffic (FTP, HTTP) are generated on same network topology with two scenarios run for each type of traffic (single flow, compete flow). Project results have shown a poor performance of TCP over IPv6 in terms of a lot of packet loss and long delay (measured RTT).

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((Work; so Allah will see your work and (so will) His Messenger and the believers;))

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LIST OF EQUATIONS

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$\text{ssthresh} = \max(\text{FlightSize} / 2, 2 * \text{SMSS})$(3).....	8

LIST OF ABBREVIATIONS

IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
TCP/IP	Transmission Control Protocol/Internet Protocol
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
IP	Internet Protocol
<i>rwnd</i>	Receiver's advertised window
<i>cwnd</i>	Congestion window
<i>ssthresh</i>	Slow Start THRESHold
ACK	ACKnowledgment
RTO	Retransmission Time Out
IW	initial value of <i>cwnd</i>
SMSS	Sender Maximum Segment Size
LW	loss window
IETF	Internet Engineering Task Force

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Transmission Control Protocol/Internet Protocol (TCP/IP), the most common of all network protocol suites, used for communication on the Internet. TCP/IP is a hierarchical protocol made up of interactive layers (as shown in Figure 1) each layer has a specific functionality.

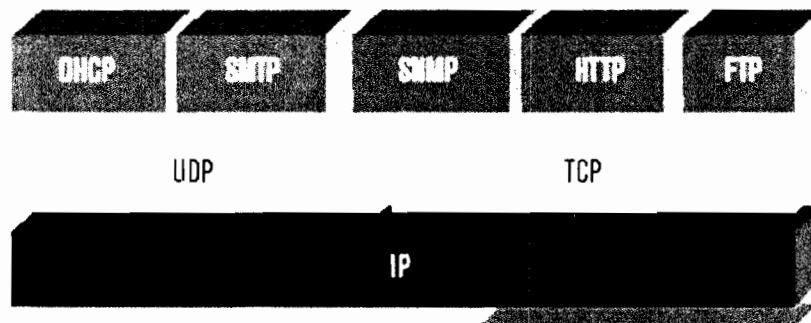


Figure 1. TCP/IP Protocol Suite

Application layer are placed at the top of TCP /IP stack, it defines protocols such as (FTP, HTTP, Telnet and so on) for application communication. These protocols are acting as interface for the actual application program.

The transport layer follows the application layer. TCP/IP makes available two distinct transport layer protocols to the application layer: Transmission Control Protocol (TCP) and User Datagram Protocol (UDP). TCP provides reliable, connection-oriented services to the invoking application [KR05] and also provides congestion control [APS99, S97, J95]. However, the congestion control is not so much a service provided to the invoking application as it is a service for the Internet as a whole [KR05]. For a more detailed introduction to TCP, see [KR05].

The contents of
the thesis is for
internal user
only

BIBLIOGRAPHY

- [AF99] M. Allman and A. Falk. On the Effective Evaluation of TCP. *ACM Computer Communication Review*, October 1999.
- [APS99] M. Allman, V. Paxson, and W. Stevens. TCP Congestion Control. RFC 2581, IETF, April 1999.
- [B99] Bajaj, s ; Breslau, L ; Estrin, D ; Fall, K ; Floyd, S ; Haldar, P ; Handley, M ; Helmy, A ; Heidemann, J ; Huang, P ; Kumar, S ; McCanne, S ; Rejaie, R ; Sharma, P ; Varadhan, K ; Xu, Y ; Yu, H & Zappala, D . (Eds). (1999). *Improving Simulation for Network Research*. Accepted by IEEE.
Retrieved, June, 1, 2006, from <http://www.isi.edu/~johnh/PAPERS/Bajaj99a.html>
- [C06] Cisco. *Building Scalable Cisco Internetworks*. USA: Cisco System, 2006.
- [CK74] V. Cerf and R. Kahn. A Protocol for Packet Network *Intercommunication*. *IEEE Transactions on Communications*. 22(5): 637 – 648. May 1974.
- [CPC05] S. Chang, J. Park and M. Y. Chung. Performance Comparison of TCP Traffic over Mobile IPv4 and IPv6 Networks and a Mobile Network Deployment Approach. In *Proceedings of the 2005 The Fifth International Conference on Computer and Information Technology (CIT'05)*. IEEE Computer Society, 2005.
- [DH98] S. Deering and R. Hinden. Internet Protocol, Version 6 (IPv6) Specification. RFC 2460, IETF, December 1998.
- [E01] T. Ernst. *MobiWan: A NS-2.1b6 simulation platform for Mobile IPv6 in Wide Area Networks*, www.inrialpes.fr/planete/mobiwan/Documents/mobiwan-report-0501.pdf.
- [F00] B. Forouzan. *TCP/IP Protocol Suite*. Boston: MCGrawHill, 2000.
- [FF96] K. Fall and S. Floyd. Simulation-based Comparison of Tahoe, Reno and SSACK TCP. *Computer Communication Review*, 26(3), July 1996.
- [FF99] S. Floyd and K. Fall. Promoting the use of end-to-end congestion control in the Internet. *IEEE/ACM Transactions on Networking*, 7(4), August 1999.
- [FK02] S. Floyd and E. Kohler. Internet Research Needs Better Models. First Workshop on the Hot topics in Networks, Princeton, New Jersey, October 2002.

- [FP01] S. Floyd and Vern Paxson. Difficulties in Simulating the Internet. *IEEE/ACM Transaction on Networking*, 9(4), August 2001.
- [H05] G. Huston. TCP Performance. Retrieved June.12,2006 from http://www.cisco.com/web/about/ac123/ac147/ac174/ac196/about_cisco_ipj_archive_article09186a00800c8417.html. 2005.
- [H96] R. Hinden. IP Next Generation Overview. *Communications of the ACM*, 39(6): 61-71, June 1996.
- [HJ04] M. Hassan and R. Jain. High Performance TCP/IP Networking Concepts, Issues, and solutions. London: Prentice Hall, 2004.
- [HM00] H. Huang and J. Ma. IPv6 - Future Approval Networking. IEEE, 2000.
- [H96] J. Hoe. Improving the Start-up Behavior of a Congestion Control Scheme for TCP. In ACM SIGCOMM, August 1996.
- [J95] V. Jacobson. Congestion avoidance and control. In the proceedings of ACM SIGCOMM Special Interest Group on Data Communications, 18(4): 314 - 329, August 1988.
- [KR05] J. Kurose and K. Ross. Computer Networking: A Top-Down Approach Featuring the Internet 3rd ed. Boston: Addison-Wesley, 2005.
- [LY00] Y. Lai and C. Yao. The Performance Comparison between TCP Reno and TCP Vegas. In the *proceedings of IEEE International Conference on Parallel and Distributed Systems*, pp.61 – 66, July 2000.
- [NS06] The Network Simulator ns-2: Documentation. July 2006. <http://www.isi.edu/nsnam/ns/ns-documentation.html>
- [O06] OMNet++: User Manual. URL: <http://www.omnetpp.org/doc/manual/usman.html>, 2006.
- [OP03] M. S. Obaidat and G. I. Papadimitiou. Applied System Simulation: Methodologies and Applications. Kluwer, 2003.
- [P01] K. Pentikousis . Can TCP be the transport protocol of the 21st century? *ACM Crossroads*, 7(2), December 2000.
- [P81] J. Postel. Transmission Control Protocol. RFC 793, IETF, September 1981.
- [PF97] V. Paxson and S. Floyd. Why we don't know how to simulate the Internet. 1997

- [PH03] Damien Phillips and Jiankun Hu. Simulation Study of TCP Performance Over Mobile IPV4 and Mobile IPV6. In *ICEIS (4)*, pages 224.231, 2003.
- [R95] R. Atkinson. IP Authentication Header. RFC 1826, IETF, 1995.
- [R95] R. Atkinson. IP Encapsulating Security Payload (ESP). RFC 1826, IETF, August 1995.
- [RVZ04] M. Rossi, R. Vicenzi and M. Zorzi. Accurate analysis of TCP on channels with memory and finite round-trip delay. *IEEE Transactions on Wireless Communications*, 3(2) – 640, 2004.
- [RZ03] I. Raicu and S. Zeadally. Impact of IPv6 on End-User Applications. In *the proceedings of IEEE International Conference on Telecommunications*, 2(23): 973 - 980, March 2003.
- [S97] W. Stevens. TCP Slow Start, Congestion Avoidance, Fast Retransmit, and Fast Recovery Algorithms. RFC 2001, IETF, January 1997.
- [SKV03] B. Sikdar, S. Kalyanaraman and K. Vastola. Analytic models for the latency and steady-state throughput of TCP Tahoe, Reno, and SACK. *IEEE/ACM Transactions on Networking*, 11(6): 959 – 971, December 2003.
- [TL01] J. Tian and Z. Li. The Next Generation Internet Protocol and Its Test. In *the proceedings of IEEE International Conference on Communications*, 1:210 - 215, June 2001.
- [WOO03] A. Wierman, T. Osogami and J. Ols'en . A unified framework for modeling TCP-Vegas, TCP-SACK, and TCP-Reno. . In *the proceedings of MASCOTS 2003. 11th IEEE/ACM International Symposium*, 269 – 278. 2003.
- [YY05] X. L. YiWang and S. Ye. Understanding Current IPv6 Performance: A Measurement Study. In *Proceedings of the 10th Symposium on Computers and Communications (ISCC 2005)*. IEEE Computer Society, 2005.