

PREETHI NATARAJAN

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Education

Ph.D. in Computer and Information Sciences

Exp. Dec 2008

University of Delaware

Advisor: Dr. Paul Amer

M.S. in Computer and Information Sciences

Aug 2003

University of Delaware

M.Sc. (Tech.) in Information Systems

May 2001

Birla Institute of Technology and Sciences, Pilani, India

Research Interests

- End-to-end issues in transport protocols such as congestion, and flow control
- Leveraging innovative transport layer services for improved application performance
- Protocol engineering and implementation

Publications

- Preethi Natarajan, Fred Baker, and Paul D. Amer, *Multiple TCP Connections Improve HTTP Throughput – Myth or Fact?*, in progress.
- Preethi Natarajan, Nasif Ekiz, Ertugrul Yilmaz, Paul D. Amer, Janardhan Iyengar, and Randall R. Stewart, *Non-Renegable Selective Acknowledgements (NR-SACKs) for SCTP*, International Conference on Network Protocols (ICNP), Orlando, October 2008.
- Preethi Natarajan, Paul D. Amer, and Randall Stewart, *Web over Multistreamed Transport for Developing Regions*, ACM SIGCOMM Workshop on Networked Systems for Developing Regions (NSDR), Seattle, August 2008.
- Preethi Natarajan, Paul D. Amer, Ertugrul Yilmaz, Randall R. Stewart, Janardhan R. Iyengar, *Non-Renegable Selective Acknowledgments for SCTP*, IETF Draft – draft-natarajan-tsvwg-sctp-nrsack, in progress.
- Preethi Natarajan, Nasif Ekiz, Janardhan Iyengar, Paul D. Amer, and Randall R. Stewart, *Concurrent Multipath Transfer using SCTP Multihoming: Introducing Potentially-failed Destination State*, IFIP International Conference on Networking (Networking), Singapore, May 2008.
- Preethi Natarajan, Janardhan R. Iyengar, Paul D. Amer, and Randall R. Stewart, *Concurrent Multipath Transfer Using Transport Layer Multihoming: Performance Under Network Failures*, IEEE Military Communications Conference (MILCOM), Washington D.C., October 2006.
- Preethi Natarajan, Janardhan R. Iyengar, Paul D. Amer, and Randall R. Stewart, *SCTP: An innovative transport layer protocol for the web*, 15th International Conference on World Wide Web (WWW), Edinburgh, May 2006.

Technical Reports

- Preethi Natarajan, Paul D. Amer and Randall Stewart, *The Case for Multistreamed Web Transport in High Latency Networks*, Technical Report: #2007-342, CIS Department, University of Delaware, October 2007.
- Preethi Natarajan, Nasif Ekiz, Paul D. Amer and Randall R. Stewart, *Concurrent Multipath Transfer Using SCTP Multihoming: Transmission Policies using Potentially-failed Destination State*, Technical Report: #2007-338, CIS Department, University of Delaware, February 2007.
- Ilknur Aydin, Renwei Ge, Preethi Natarajan, and Chien-Chung Shen, *Performance Evaluation of SCTP in Mobile Ad Hoc Network*, Technical Report #2005-18, CIS Department, University of Delaware, May 2005.

Work Experience

Research Intern at Cisco Systems Inc. (Summer 2008)

To improve response times, web browsers typically download HTTP transactions over multiple TCP connections. On-going investigations look at the dynamics between multiple TCP senders and HTTP throughput, especially in low bandwidth last miles found in developing regions. Initial analysis exposed interactions between multiple TCP senders that hurt HTTP performance.

Summer Intern at Google Inc., Mountain View, California (Summer 2007)

Adapted open source network performance benchmark tool - Netperf4 (www.netperf.org) to work on custom built clusters. Designed and developed new tests to gather operating system, transport, and network device level performance numbers. The new tests have been merged into Netperf4's main trunk.

Research Intern at University of Vienna, Austria (Summer 2006)

Worked at the Distributed and Multimedia Systems lab. Built a virtual reality tool which uses OpenGL to (i) generate and project images to a 3D stereo visor, and (ii) continuously track the user's head movements and re-draw the visor image based on the latest head position. The tool was integrated into a virtual reality application for Wien Energy.

Software Engineer at Hewlett-Packard, India (November 2003 - July 2004)

Worked with HP's Grid team to port Globus Toolkit (GTK) - an open source grid middleware, to HP-UX and Tru64 platforms. Developed tools to setup and install GTK and related grid software on multiple machines in parallel. Involved in setting up computational grids at the Indian Institute of Science's Physics and Computer Science departments.

Research Experience

Research Assistant at Protocol Engineering Lab (Fall 2004 - Present)

Non-Renegable Selective Acknowledgements (NR-SACKs)

In both TCP and SCTP, selectively acked (SACKed) out-of-order data is implicitly renegable; that is, the receiver can later discard SACKed data. The possibility of renegeing forces the transport sender to maintain copies of SACKed data in the send buffer until that data is cumulatively acked. Out-of-order data is non-renegable when the data has been delivered to the application, or when the receiver simply never reneges. In such situations SACKs waste send buffer space. The amount of wasted memory increases as the frequency of loss events and loss recovery durations increase. We introduce a fundamentally new ack mechanism, Non-Renegable Selective Acknowledgments (NR-SACKs), for SCTP. Using NR-SACKs, an SCTP receiver can explicitly identify some or all out-of-order data as being non-renegable, allowing the sender to free up buffer space sooner than if the data were only SACKed. We compare and show that NR-SACKs enable efficient utilization of a transport sender's memory, and improve throughput. We are currently working on an Internet draft to standardize NR-SACKs for SCTP.

Web over Multistreamed Transport

Objects embedded within a web page are independent of each other. That is, requesting and displaying an object does not depend on the reception of other objects. When multiple objects are transferred over a single TCP bytestream, loss of one object blocks delivery of other successfully received objects. This problem, known as head-of-line (HOL) blocking, occurs because TCP cannot logically separate independent application level objects in its transport and delivery mechanisms. Transport layer streams are logical unidirectional pipes with independent sequencing space. Transferring independent web objects over different streams of a multistreamed transport connection reduces HOL blocking. We designed HTTP over SCTP streams, and implemented the design in the Apache (v2.0.55) web server, and Firefox (v1.6a1) browser. Initial performance results over high latency paths reveal that SCTP enables faster page downloads and visually perceivable improvements to pipelined objects' response times.

HTTP over SCTP in Firefox Distribution

This is an on-going effort to integrate our HTTP over SCTP design and implementation into the Firefox distribution from mozilla.org. The current activity is focused on establishing SCTP awareness in the Netscape Portable Runtime (NSPR) API, which offers platform independent network, I/O, and threading implementations to Firefox and a host of other Mozilla applications. Subsequent work will focus on modifying Firefox to take advantage of NSPR's SCTP related API calls.

CMT during Path Failures

Concurrent Multipath Transfer (CMT) is an experimental SCTP extension that assumes multiple independent paths between end hosts, and exploits the paths for simultaneous transfer of new data. We investigated CMT's throughput degradation during path failures, and proposed CMT with a new Potentially-failed destination state (CMT-PF) to improve performance. Ns-2 simulation results show that CMT-PF outperforms CMT during permanent and short-term failures. CMT-PF has been implemented in the FreeBSD SCTP reference implementation.

Improving File Transfers using SCTP Multistreaming

We evaluated three FTP over SCTP implementations: (1) similar to FTP/TCP with one SCTP association for control and another for each file transfer, (2) using a persistent SCTP association with 2 streams, where 1 stream is used for control and the other is used for all file transfers, and (3) enhancing (2) with command pipelining in the control stream. Emulation results show that (3)'s most efficient bandwidth utilization enables better performance compared to (1), (2), and native FTP over TCP.

Extensions to TCP Behavior Inference Tool (TBIT)

TBIT tests infer specific characteristics and/or parameter values of a web server's TCP implementation. We extended the TBIT test suite to include detection for algorithm implementations such as Eifel, Forward RTO-Recovery, and ECN Nonce. The extensions also included tests to discover parameter values for duplicate ack threshold, congestion window after timeout, default MSS, and minimum RTO. Initial results from TCP implementations around the world revealed unusual values for the default MSS and receiver buffer sizes.

Research Assistant (Summer 2002)

Worked with Dr. Constantinos Dovrolis, and implemented the Proportional Differentiated Services (PDS) architecture in ns-2. PDS was developed by Dr. Dovrolis, and guarantees relative and controllable service differentiation between classes. This guarantee is realized via proportional class differentiation during packet scheduling and buffer management at the router queue.

Software

New Tests in Netperf4

Designed and developed new tests for the open source network performance benchmark tool Netperf4 (www.netperf.org). These new tests are now part of Netperf4's main trunk.

Apache over SCTP

Implemented HTTP over SCTP streams in Apache's httpd web server (www.apache.org) Modified the Apache Portable Runtime (APR), and the httpd server's core module for HTTP transactions.

Firefox over SCTP

Implemented HTTP over SCTP streams in Mozilla's Firefox browser (www.mozilla.org). Introduced new SCTP related APIs in the Netscape Portable Runtime (NSPR), and modified HTTP request-response processing in the HTTP module.

Maintain SCTP and CMT Module in ns-2

Added new functionalities, and involved in the maintenance of University of Delaware's ns-2 SCTP and CMT modules.

Awards

University of Delaware Alumni Enrichment Award

\$2K travel grant for Networking 2008, Singapore, May 2008.

\$2K travel grant for WWW2006, Edinburgh, Scotland, May 2006.

Professional Services

- Reviewer, The Handbook of Computer Networks (John Wiley & Sons, Inc.)
- Reviewer, SI on Concurrent Multipath Transfer, Computer Communications, 2006, 2008
- Reviewer for NTMS 2007, Networking 2006, INFOCOM 2006, ICNP 2005, ISCC 2005

Talks

- *Concurrent Multipath Transfer using Transport Layer Multihoming: Introducing the Potentially-failed (PF) Destination State*, IFIP International Conference on Networking (Networking 2008), Singapore, May 2008.
- *Non-Renegable Selective Acknowledgments (NR-SACKs) for SCTP*, TSVWG Session, 71st IETF, Philadelphia, March 2008.
- *Overview of Network simulator (NS-2)*, Guest lecture for graduate level course titled Simulation of Computer Networks, CIS Dept, University of Delaware, November 2007.
- *Adapting Firefox and NSPR to work over SCTP streams*, Google Inc., July 2007.
- *Leveraging Multistreaming and Multihoming Transport Layer Services for Improved Application Performance*, PhD Qualifying Exam, University of Delaware, December 2006.
- *Concurrent Multipath Transfer using Transport Layer Multihoming: Performance during Network Failures*, IEEE Military Communications Conference (MILCOM), Washington D.C., October 2006.
- *TCP Performance in Mobile Ad-Hoc Networks*, Class of Wireless Networks and Mobile Computing, University of Delaware, Fall 2004.
- *Voice Web and VoiceXML*, Class of Advanced Software Design, University of Delaware, Spring 2003.
- *Explicit Congestion Notification in TCP/IP*, Class of TCP/IP and Upper Layer Protocols, University of Delaware, Fall 2002.