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RESEARCH INTERESTS

The focus of my research is to make networks adaptable, evolvable, self-managed, and cost-efficient as well as improve their performance. To that end, my research interests lie in several areas of Networking including congestion control, routing, protocol design, router/switch architectures in both wired as well as wireless networks. I want to build and experiment with networking systems while making use of theoretical analysis where applicable. I am particularly enthusiastic in collaborating with disciplines outside of Networking.

EDUCATION

Stanford University — Stanford, CA
Ph.D. in Electrical Engineering — Expected June 2007
Thesis: Rate Control Protocol (RCP): Congestion Control to Make Flows Complete Quickly

Indian Institute of Science — Bangalore, India
M.S. in Electrical Engineering — August 2000
Thesis: Optimal Resource Allocation in Packet Networks

Birla Institute of Technology and Science — Pilani, India
B.E.(Hons) in Electronics and Instrumentation — June 1998
Thesis: PC-based Fiber Optic Sensing System to measure angular displacement

Ph.D. DISSERTATION

Title: "Rate Control Protocol (RCP): Congestion Control to Make Flows Complete Quickly"
Advisor: Professor Nick McKeown
Thesis Committee: Balaji Prabhakar, Mendel Rosenblum, Scott Shenker

Users typically want their flows to complete as quickly as possible. This makes Flow Completion Time (FCT) an important - arguably the most important - performance metric for the user. Yet research on congestion control focuses entirely on maximizing link throughput, utilization and fairness, which matter more to the operator than the user. My thesis is about a new congestion control algorithm - Rate Control Protocol (RCP) - designed for fast download times (i.e. aka user response times, or flow-completion times). Whereas other modifications/replacements to TCP (e.g. STCP, Fast TCP, XCP) are designed to work for specialized applications that use long-lived flows (scientific applications and supercomputer centers), RCP is designed for the typical flows of typical users in the Internet today.

I showed that with typical Internet flow sizes, existing (TCP Sack) and newly proposed (XCP) congestion control algorithms make flows last much longer than necessary - often by one or two orders of magnitude. In contrast, RCP makes flows finish close to the minimum possible, leading to a perceptible improvement for web users, distributed computing, and distributed file-systems. I have also addressed several questions for an RCP network - stability of an RCP network, coping with sudden network changes such as flash-crowds (the main weakness under RCP), RCP's router buffer-size requirements, proportional bandwidth-sharing with RCP and implementation of RCP in routers and end-hosts.

RESEARCH EXPERIENCE

THESIS RESEARCH

2002 – Present *Research Assistant, Computer Systems Laboratory, Stanford University*

Minimizing Flow-completion Times in a Network (Jan 2002 – July 2003): How would we design congestion control to minimize download times? Unfortunately, it is intractable to find an optimal solution for a general network under arbitrary flow arrivals and departures. I found that under a more constrained problem of allotting a single rate to all flows, there exists a rate that minimizes flow-completion times for heavy-tailed flow sizes (which they are in the Internet). This finding became the basis of RCP congestion control algorithm.

Rate Control Protocol (RCP) Congestion Control (Jan 2003 – Present)**:** I designed a congestion control algorithm (RCP) which heuristically updates the rate it offers to all flows passing through a link and achieves flow-completion times close to an ideal processor-sharing system. The algorithm requires no per-flow state/queue and decides the offered rate based only on the queue-size, aggregate traffic and average round-trip time of flows, making it simple and practical.

Network Stability under RCP (Sept 2003 – Dec 2004): A desirable characteristic of any congestion control mechanism is that it be stable even under sudden unexpected changes in traffic load. Using control-theory I proved that a linearized model of RCP congestion control is stable for a broad range of network and traffic conditions. In collaboration with control-theorists RCP stability was later extended to the more realistic non-linear system as well as for traffic conditions involving dynamic flow arrivals/departures.

Buffer-size requirements under RCP (Jun 2006 - Present): Buffer-sizing in Internet routers has recently received attention because of its huge implications on cost and complexity of router design. Along with a colleague, I analyzed the amount of buffering needed by RCP routers for a bounded packet loss probability. Analysis and simulations indicate that buffers have to scale with link-capacities, however a fraction of the bandwidth delay product (often as little as 5%) is sufficient to maintain flow-completion times that are at most 20% larger than FCTs under very large buffers.

Implementing RCP Congestion Control in Linux (Jun 2006 - Present): Implemented congestion control mechanisms of the RCP end-host in Linux 2.6.16.

OTHER RESEARCH

Sept 06 – Present *Research Assistant, Stanford University (collaboration with Cisco Systems, San Jose, CA)*

Making a case for explicit network feedback for Congestion Control: There is no current widespread deployment of explicit feedback mechanisms. Our goal is to create a compelling demonstration on how user-experience will be perceptibly better (examples include downloading High Definition video, web-browsing, file-system applications, on-line games) if the network explicitly participated in congestion control and ultimately making a case on why router/switch vendors should be interested in explicit feedback schemes.

Summer 2005 *Research Assistant, Computer Systems Laboratory, Stanford University*

Typical versus Worst Case Design in Networking: Observed that Networking research has a strong inclination toward designing systems for the worst-case scenarios. While designing for the worst case gives strong guarantees on the system, it often comes with a high cost and a sacrifice for the typical case performance. Along with colleagues, I demonstrated (through examples) that it is possible to design systems for the typical-case to reap the enormous benefits in performance, cost and complexity, without overly hurting the worst-case.

Summer 2004 *Research Intern, Fraser Research, Princeton, NJ*
Designing congestion control for zero packet-loss and fast flow-completion times: Packet loss is detrimental to many applications, video-on-demand, online gaming and data-center applications being the most notable of them. Although RCP congestion control finishes flows quickly, there are no guarantees of zero loss. I designed RCP-AC (RCP with Acceleration Control) – a tunable congestion control algorithm that can be adapted to achieve zero packet loss at one end of the spectrum and short flow-completion times at the other extreme. RCP-AC allows an operator to choose the operating point, and control packet loss, while still allowing flows to finish much more quickly than in conventional algorithms.

Summer 2002 *Research Intern, Bell Labs, Lucent Technologies, Holmdel, NJ*
Prefix Allocation to Minimize Routing Table Sizes: As the Internet grows rapidly one of the problems facing the backbone routers today is the increasing size of the routing table. Solved the problem of allocating prefixes to the network nodes in order to minimize the maximum routing table size in the network.

1998 - 2000 *Research Assistant, Indian Institute of Science, Bangalore, India*
Optimal Resource Allocation in Packet Networks: A key issue in delivering Quality-of-Service guarantees is resource allocation at the network nodes to satisfy the end-to-end delay requirements. Devised and implemented algorithms to determine the optimal capacity allocation satisfying end-to-end delay requirements in a network of Generalized Processor Sharing (GPS) schedulers. Demonstrated that these algorithms outperform previously proposed algorithms.

Aug-Dec 1997 *Undergraduate Researcher, Birla Institute of Technology and Science, Pilani, India*
PC-based Fiber Optic sensing system: Designed a PC based fiber optic sensing system that measures the angular displacement and Numerical Aperture of the fiber.

WORK EXPERIENCE

Aug 2000 - 01 *Research Associate, Himachal Futuristic Communications Limited, Bangalore, India*
Network Topology Design Tool: Designed and implemented computationally efficient heuristic algorithms for a Network Topology Design Tool. The tool helps ISPs in deciding the placement of routers in the network, topology connecting the routers and the optimal flow paths, all in a cost-effective way.

Jan–Jun 1998 *Intern, Honeywell India Software Operations, Bangalore, India*
Developed a client-server package in C++ that lets a mobile user access, monitor and control a Building Management System using a handheld PC. The server lets the remote client to access various sites of the corporate without having the need to connect to the individual sites. The client software provides a user-friendly interface.

TEACHING EXPERIENCE

Winter 2006 *Teaching Assistant, Electrical Engineering Department, Stanford University*
EE384X, Packet Switch Architectures-I (Graduate-level Networking class)**:** Teaching Assistant to Prof. Balaji Prabhakar and Prof. Nick McKeown. Prepared and gave lectures for material not covered in class. Formulated questions for homework sets, quizzes and midterm/final examinations, graded exams and interacted with students during weekly office hours.

Spring 2006 *Teaching Assistant, Electrical Engineering Department, Stanford University*
EE384Y, Packet Switch Architectures-II (Graduate-level Networking class)**:** Teaching Assistant to Prof. Balaji Prabhakar and Prof. Nick McKeown. Designed and graded homework sets, quizzes and examinations as well as guided students during the weekly office hours.

PUBLICATIONS

PAPERS

- N. Dukkipati, N. McKeown, A. G. Fraser, "RCP-AC: Congestion Control to make flows complete quickly in any environment," *High-Speed Networking Workshop: The Terabits Challenge (in conjunction with IEEE INFOCOM 2006)*, Barcelona, Spain, Jun 2006.

- N. Dukkipati, N. McKeown, "Why Flow-Completion Time is the Right Metric for Congestion Control," *SIGCOMM Computer Communications Review*, Vol. 36, No. 1, Jan. 2006.

- N. Dukkipati, Y. Ganjali, R. Zhang-Shen, "Typical versus Worst Case Design in Networking," *Fourth Workshop on Hot Topics in Networks (HotNets-IV)*, College Park, Nov 2005.

- N. Dukkipati, M. Kobayashi, R. Zhang-Shen, N. McKeown, "Processor Sharing Flows in the Internet," *Thirteenth International Workshop on Quality of Service (IWQoS 2005),* Passau, Germany, Jun 2005.

- A. Panagakis, N. Dukkipati, I. Stavrakakis, J. Kuri, "Optimal Call Admission Control on a Single Link with GPS Scheduler*," IEEE/ACM Transactions on Networking, vol. 12, No. 5*, Oct 2004.

- N. Dukkipati, J. Kuri, H.S. Jamadagni, "Optimal Call Admission Control in Generalized Processor Sharing (GPS) Schedulers," *Proceedings of IEEE INFOCOM*, Anchorage, April 2001.

- N. Dukkipati, J. Kuri, H.S. Jamadagni, "Optimal Resource Allocation in Packet Networks that use Rate-Based Schedulers," *IEEE Conference in Communications, Controls and Signal Processing (CCSP 2000),* Bangalore, July 2000.

PENDING PAPERS, INTERNET DRAFT

- A. Lakshmikantha, N. Dukkipati, R. Srikant, N. McKeown, C.L. Beck, "Performance Analysis of the Rate Control Protocol," Under preparation to *ACM Computer Communications Review*.

- H. Balakrishnan, N. Dukkipati, N. McKeown, C. Tomlin, "Stability Analysis of Explicit Congestion Control Protocols," Under submission to *IEEE Communications Letters*.

- N. Dukkipati, G. Gibb, N. McKeown, "Implementation and Experiments with the Rate Control Protocol (RCP)," Under preparation.

- N. Dukkipati, N. McKeown, F. Baker, "Implementing RCP in the IPv6 Hop-by-Hop Options Header," *Internet Draft* in preparation.

- N. Dukkipati, N. McKeown, "Rate Control Protocol (RCP): Congestion Control to Make Flows Complete Quickly," Under preparation to the *IEEE/ACM Transactions on Networking*.

TECHNICAL REPORTS

- A. Lakshmikantha, N. Dukkipati, R. Srikant, N. McKeown, C.L. Beck, "Performance Analysis of the Rate Control Protocol," *UIUC Technical Report*, December 2006.

- N. Dukkipati, N. McKeown, "Why Flow-Completion Time is the Right Metric for Congestion Control," *Stanford High Performance Networking Group Technical Report TR05-HPNG-112102*, November 2005.

- H. Balakrishnan, N. Dukkipati, N. McKeown, C. Tomlin, "Stability Analysis of Explicit Congestion Control Protocols," *Stanford University Department of Aeronautics and Astronautics Report: SUDAAR 776,* September 2005.

- N. Dukkipati, N. McKeown, "Processor Sharing Flows in the Internet," *Stanford High Performance Networking Group Technical Report TR04-HPNG-061604*, June 2004.

- N. Dukkipati, "Optimal Resource Allocation in Packet Networks," *Masters Thesis, Indian Institute of Science*, September 2000.

PATENTS

P. Chaporkar, N. Dukkipati, J. Kuri, A. Kumar, "Method for Fast Cost-effective Internet Topology Design," United States Patent Application Number 10/614,683, July 2003.

TALKS

CONFERENCES, ACADEMIA, RESEARCH LABS

- (*at several venues*) "RCP: Congestion Control to Make Flows Complete Quickly"
  - Microsoft Research, Redmond, Sept 2006
  - (*Invited by Craig Partridge*) End2End Meeting, MIT, Cambridge, July 2006
  - (*Invited by Prof. Steven Low*) Caltech Lunch Bunch Seminar, Nov 2005
  - Berkeley Systems Lunch, Oct 2005
  - (*Invited by Prof. Robert Shorten*) Hamilton Institute Workshop on Congestion, Sept 2005
  - (*Invited by Prof. Scott Shenker*) International Computer Science Institute (ICSI), July 2005
  - International Workshop on Quality of Service (IWQoS), Passau, Germany, June 2005
  - (*Invited by Prof. Jim Kurose*) University of Massachusetts at Amherst, April 2005
  - MIT CSAIL, April 2005

- "RCP: Prototyping, Demonstrating and Solving Deployment Questions," *Stanford, CA*, Sept 2006

- "RCP-AC: Congestion Control to Make Flows Complete Quickly in any Environment," *High Speed Networking Workshop: The Terabits Challenge, Infocom 2006, Barcelona, Spain*, April 2006

- "Designing Congestion Control for Fast Flow-completion Times," *100x100 Clean Slate Retreat, Houston*, Dec 2005

- (*Invited to be on a panel on Structure and Protocol Design*) "Using Simple Structures to Achieve Complex Properties," *100x100 Clean Slate Retreat, Houston*, Dec 2005

- "Typical versus Worst-case Design in Networking," *Fourth Workshop on Hot Topics in Networks, HotNets-IV*, Nov 2005

- "Congestion control in 100x100: Why TCP is a poor choice and how to redesign it from scratch," *100x100 Clean Slate Retreat, Pittsburgh*, Dec 2004

- "Optimal Resource Allocation in Packet Networks*," IEEE INFOCOM 2001, Anchorage, Alaska, USA*, April 2001

INDUSTRY

- "A Wish List for the next Congestion Control Protocol and Why TCP may not get us there," *Cisco-Stanford Meeting, Cisco Systems, San Jose*, Oct 2006
- "Making a case for Explicit Feedback for Congestion Control," *Cisco-Stanford Meeting, Cisco Systems, San Jose*, Nov 2006
- (*At several venues*) "RCP: Congestion Control to Make Flows Complete Quickly"
  - (*Invited by John Wakerly*) *Cisco Distinguished Engineers/Fellows Meet, Cisco Systems, San Jose*, July 2005
  - (*Invited*) Cisco Network Architecture Geeks (NAG) Conference, Cisco Systems, San Jose, July 2006
  - (*Invited*) Boeing Aerospace Corporation, June 2006
  - (*Inivited by Jean Bolot, Sprint ATL CTO*) Sprint Advanced Technology Labs, Burlingame, CA, USA, Oct 2005
  - (*Invited by Flavio Bonomi, DE Cisco Systems*) Cisco Systems, San Jose, July 2005

PROFESSIONAL ACTIVITIES

Ad-hoc Reviewer for IEEE/ACM Transactions on Networking, IEEE Communications Letters, ACM SIGCOMM Computer Communications Review, ACM SIGCOMM 2006, 2002, ACM/IEEE ANCS 2005, IEEE INFOCOM 2003.

REFERENCES

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