

Alex C. Snoeren

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Education

Massachusetts Institute of Technology

- 2002 PhD in Electrical Engineering and Computer Science (*Summer completion expected*)
Dissertation: *An End-to-End Approach to Internet Mobility*
Hari Balakrishnan and M. Frans Kaashoek, advisors
Minor in Public Policy (at the Harvard JFK School of Government)

Georgia Institute of Technology

- 1997 MS in Computer Science
BS in Applied Mathematics (*summa cum laude*)
1996 BS in Computer Science (*summa cum laude*)

Research interests

Many aspects of computer systems, especially operating systems, networking, and mobile and distributed systems. Particularly interested in scalable services and protocols to support secure, robust wide-area mobile internetworking.

Employment summary

- 1997– **Massachusetts Institute of Technology**
Research assistant in the Advanced Network Architecture, Networks & Mobile Systems, and Parallel & Distributed Operating Systems groups of the Laboratory for Computer Science
- 1999– **BBN Technologies**
Research scientist in the Internetworking Research department
- 1995–7 **Hewlett-Packard Research Labs**
Research intern in the Performance, Management & Design group of the Software Technology lab
- 1994 **NASA Lewis (Glenn) Research Labs**
Summer research intern in the Electro-Physics branch

Teaching experience

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

- 2001 **Instructor** – 6.033: *Computer Systems Engineering*
A position usually held by a member of the faculty. Prepared and taught weekly recitation sessions centered around the discussion of current and seminal papers in computer systems. The core MIT undergraduate systems course, 6.033 is a broad survey of the field of computer systems, including modularity, concurrency, file systems, networking, fault tolerance, etc.
- 1998 **Recitation instructor** – 6.821: *Programming languages*
Taught weekly recitation sections to about 25 students. Answered students' questions, graded problem sets, led quiz reviews. Developed course material, including problem sets, exams, and Scheme code.

GEORGIA INSTITUTE OF TECHNOLOGY

- 1997 **Teaching assistant** – CS 4345: *Computerization and Society*
Lead classroom discussions, answered questions, graded reports, and helped students with writing assignments on the societal impact of computing.
- 1994–7 **Recitation instructor** – CS 2360: *Knowledge Representation and Process* (**Six terms**)
Taught weekly lab/recitation section of approximately 30 students. Developed course assignments and code base, answered questions, graded assignments, and assisted students with LISP.
- 1996 **Teaching assistant** – CS 3361: *Artificial Intelligence*
Graded programming assignments, answered questions, and helped develop class assignments.
- 1995 **Recitation instructor** – CS 2430: *Control and Concurrency*
Taught weekly lab/recitation section of approximately 30 students. Answered questions, graded assignments, and assisted students with C. Lectured to class of 250 students in professor's absence on IPC and synchronization. Nominated by the course instructor for the graduate teaching award as an undergrad.
- 1994 **Recitation instructor** – CS 1501: *Introduction to Computing* (**Two terms**)
Assisted in the development of a new introductory course in computer science. Taught weekly recitation and lab sections of 25 students, graded homework, quizzes, and exams, designed and taught review sessions, and helped students learn a special-purpose Pascal-like language used in the course.

Advising

- 2001– M. Eng. Thesis — *Massachusetts Institute of Technology*
Along with Hari Balakrishnan, co-supervise Jon Salz, a student whose M. Eng. thesis on *TESLA: A Transparent Extensible Session-Layer Architecture* is related to dissertation topic.
- 1995–6 Academic advisor — *SPAARC, Georgia Institute of Technology*
Assisted undergraduate students in selecting appropriate classes, choosing majors, and planning their course of study. Provided guidance for majors in the colleges of computing and sciences.

Awards

- 2001 Best Student Paper, ACM SIGCOMM
- 1997 Department of Defense National Science and Engineering Graduate Fellowship
National Science Foundation Graduate Research Fellowship (*Declined*)
- 1993–7 Georgia Institute of Technology Faculty Honors (*4.0 GPA*)
- 1996 Rhodes Scholar Finalist
Outstanding College of Computing Undergraduate, Georgia Tech
- 1993 National Merit Scholar
National Science Scholar
National Academy of Space, Science & Technology Scholar
Georgia Institute of Technology President's Scholar
- Member, ANAK Georgia Tech senior honor society
Member, Omicron Delta Kappa leadership honor society (past Alpha-Eta Circle president)
Member, Golden Key academic honor society
Member, Delta Chi fraternity

Patents

- 2002 Walter C. Milliken, Alex C. Snoeren, and Luis A. Sanchez, *Systems and Methods for Point of Ingress Traceback of a Network Attack*. Filed January 11, 2002.

Refereed publications

JOURNAL ARTICLES

- 2002 “Single-Packet IP Traceback.” Alex C. Snoeren, Craig Partridge, Luis A. Sanchez, Christine E. Jones, Fabrice Tchakountio, Beverly Schwartz, Stephen T. Kent, and W. Timothy Strayer. To appear in *IEEE/ACM Transactions on Networking (TON)*, Volume 10, 2002.
- 2001 “FIRE: Flexible Intra-AS Routing Environment.” Craig Partridge, Alex C. Snoeren, W. Timothy Strayer, Beverly Schwartz, Matthew Condell, and Isidro Castineyra. *IEEE Journal on Selected Areas in Communications (J-SAC)*, Volume 19, Number 3, March 2001.

CONFERENCE PAPERS

- 2001 “Mesh-Based Content Routing using XML.” Alex C. Snoeren, Kenneth Conley, and David K. Gifford. *Proceedings of the 18th ACM Symposium on Operating System Principles (SOSP 18)*, Banff, Canada, October 2001.
- “Hash-Based IP Traceback.” Alex C. Snoeren, Craig Partridge, Luis A. Sanchez, Christine E. Jones, Fabrice Tchakountio, Stephen T. Kent, and W. Timothy Strayer. *Proceedings of the ACM Conference on Applications, Technologies, Architectures, and Protocols for Computer Communication (SIGCOMM '01)*, San Diego, California, August 2001.
- “Hardware Support for a Hash-Based IP Traceback.” Luis A. Sanchez, Walter C. Milliken, Alex C. Snoeren, Fabrice Tchakountio, Christine E. Jones, Stephen T. Kent, Craig Partridge, and W. Timothy Strayer. *Proceedings of the Second DARPA Information Survivability Conference and Exposition (DISCEX II)*, Anaheim, California, June 2001.
- “Fine-Grained Failover Using Connection Migration.” Alex C. Snoeren, David G. Andersen, and Hari Balakrishnan. *Proceedings of the Third USENIX Symposium on Internet Technologies and Systems (USITS '01)*, San Francisco, California, March 2001.
- 2000 “FIRE: Flexible Intra-AS Routing Environment.” Craig Partridge, Alex C. Snoeren, W. Timothy Strayer, Beverly Schwartz, Matthew Condell, and Isidro Castineyra. *Proceedings of the ACM Conference on Applications, Technologies, Architectures, and Protocols for Computer Communication (SIGCOMM 2000)*, Stockholm, Sweden, August 2000.
- “An End-to-End Approach to Host Mobility.” Alex C. Snoeren and Hari Balakrishnan. *Proceedings of the Sixth Annual International Conference on Mobile Computing and Networking (MOBICOM 2000)*, Boston, Massachusetts, August 2000.
- 1999 “Adaptive Inverse Multiplexing for Wide-Area Wireless Networks.” Alex C. Snoeren. *Proceedings of the IEEE Conference on Global Communications (GLOBECOM '99)*, *Global Internet Symposium*, Rio de Janeiro, Brazil, December 1999.

WORKSHOP PAPERS

- 2001 “The Migrate Approach to Internet Mobility.” Alex C. Snoeren, Hari Balakrishnan, and M. Frans Kaashoek. *Proceedings of the Student Oxygen Workshop (SOW '01)*, Gloucester, Massachusetts, July 2001.
- “Reconsidering Internet Mobility.” Alex C. Snoeren, Hari Balakrishnan, and M. Frans Kaashoek. *Proceedings of the Eighth Workshop on Hot Topics in Operating Systems (HOTOS-VIII)*, Elmau, Germany, May 2001.
- 1998 “Automated Whole-System Diagnosis of Distributed Services Using Model-Based Reasoning.” George Forman, Mudita Jain, Masoud Mansouri-Samani, Joseph Martinka, and Alex C. Snoeren. *Proceedings of the Ninth IFIP/IEEE Workshop on Distributed Systems: Operations and Management (DSOM '98)*, Newark, Delaware, October 1998.

(All publications are available electronically from <http://nms.lcs.mit.edu/~snoeren/publications.html>)

Talks

- 2001 “Hash-Based IP Path Tracing,” IP Path Tracing (IPPT) BOF, 52nd Internet Engineering Task Force Meeting (IETF 52), Salt Lake City, Utah, December 13, 2001.
- “Mesh-Based Content Routing using XML,” 18th ACM Symposium on Operating Systems Principles (SOSP 18), Banff, Canada, October 23, 2001.
- , PEO Interchange XML Initiative (PIXIT) Meeting, The MITRE Corporation, Bedford, Massachusetts, October 16, 2001.
- “Hash-Based IP Traceback,” ACM Conference on Applications, Technologies, Architectures, and Protocols for Computer Communication (SIGCOMM '01), San Diego, California, August 29, 2001.
- , Systems Seminar, College of Computing, Georgia Institute of Technology, Atlanta, Georgia, October 18, 2001.
- “Reconsidering Internet Mobility,” Eighth Workshop on Hot Topics in Operating Systems (HotOS-VIII), Elmau, Germany, May 21, 2001.
- “Fine-Grained Failover Using Connection Migration,” Third USENIX Symposium on Internet Technologies and Systems (USITS '01), San Francisco, California, March 28, 2001.
- 2000 “FIRE: Flexible Intra-AS Routing Environment,” ACM Conference on Applications, Technologies, Architectures, and Protocols for Computer Communication (SIGCOMM 2000), Stockholm, Sweden, August 31, 2000.
- “An End-to-End Approach to Host Mobility,” Sixth Annual International Conference on Mobile Computing and Networking (MOBICOM 2000), Boston, Massachusetts, August 9, 2000.
- “TCP Connection Migration,” IRTF End-to-End Research Group Meeting, Cambridge, Massachusetts, June 23, 2000.
- 1999 “Adaptive Inverse Multiplexing for Wide-Area Wireless Networks,” IEEE Conference on Global Communications (GLOBECOM '99), Global Internet Symposium, Rio de Janeiro, Brazil, December 6, 1999.
- 1996 “PROMISE - Using Flipper for Automated System Diagnosis: A Tutorial,” HP Research Labs, Palo Alto, California, September 1996.

Service

- 1998– Referee — *GlobeCom, HotOS, MobiCom, MoMuC, SOSP, USITS, CCR, J-SAC, TOCS*
- 2000 Network Reading Group (NetRead) Organizer — *MIT Laboratory for Computer Science*
Organized weekly student-led seminars discussing recent and seminal papers in computer networking and related fields.
- 1997 Curriculum Committee Member — *Georgia Tech College of Computing*
Participated in the complete redefinition of the requirements for the Bachelors degree in computer science at Georgia Tech in preparation for the conversion from quarters to the semester system in the fall of 1999.
- Graduate senator — *Georgia Tech Student Government Association*
Served as one of two senators representing the College of Computing in the Graduate Senate.
- 1996 Computer Ownership Committee Member — *Georgia Institute of Technology*
Helped define the first mandatory computer ownership policy in the state university system, instituted in Fall 1998. Assisted the President and Provost in presenting the policy to the Georgia Board of Regents.
- 1995–6 Department representative — *Georgia Tech Student Government Association*
Served as one of two students representing the College of Computing in the Undergraduate House.

Research summary

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

- 1999– **End-to-end mobility** – Dissertation research investigates end-to-end techniques to support mobility and disconnected operation in the Internet. As Internet hosts become increasingly mobile, many applications require additional system support. Developed a mobility architecture called *Migrate* that allows session-based applications to gracefully handle changes in network attachment point as well as unexpected periods of disconnectivity. The Migrate architecture is based solely on end-host signaling and requires no additional infrastructure support.

Migrate provides programmatic system support for managing session state during periods of intermittent connectivity, and allows for the reallocation of both application and kernel resources during periods of disconnection. By constantly monitoring network connectivity, interpreting user preferences, and reacting to changes in network conditions, Migrate provides a unified framework to ease the burden of mobile-aware application programming.

An initial version of the mobility architecture, based upon a novel TCP migration scheme, was presented in 1999. A full-featured version, implemented as a session-layer service, forms the core of the thesis. A system-wide Migrate service monitors network performance and brokers session communication, guided by user- and application- specified policies. An extended Migrate API provides mobile-aware applications with advanced session-based resource management facilities, while a conformance library allows legacy applications to leverage basic mobility and disconnectivity support.

- 2001– **Robust content distribution** – Some high-value streaming applications require greater reliability and lower latency than is typically available by current Internet distribution technologies. One way to simultaneously increase reliability and decrease latency is to send redundant information over disjoint paths, sometimes called *dispersity routing*. Helped design and implement an extremely reliable and timely content streaming service by distributing data through a redundant mesh of overlay routers.

Co-designed and co-implemented the Diversity Control Protocol (DCP), which allows a receiver to intelligently reassemble a packet flow redundantly forwarded over multiple paths, enabling low-latency delivery of time-critical data in the presence of lossy channels. DCP forms the basis of a mesh-based XML content delivery network. A prototype network delivers XML-encoded real-time air traffic data in a timely and reliable fashion.

- 1997–9 **IP over wireless links** – In an effort to achieve higher data rates using current-generation wide-area wireless technologies, developed a technique to efficiently bundle shared heterogeneous links called *link quality balancing* (LQB). Unlike previous techniques, which assume stable (typically identical) performance characteristics across bundled links, LQB provides high throughput even in the presence of dynamic channel and traffic characteristics. Implemented LQB in FreeBSD's multi-link PPP module, and used it to multiplex IP traffic over bundled Cellular Digital Packet Data (CDPD) channels. Installed a prototype router (and supporting power and communication equipment) into an AMC Hummer all-terrain vehicle.

BBN TECHNOLOGIES

- 2000–9 **Denial of service detection** – Due to the anonymous nature of the IP protocol, it is impossible to reliably discern the source of an IP packet by examining it upon receipt. Increased awareness of the significant damage potential of denial-of-service attacks has motivated techniques to isolate the source of IP packets. Most known *IP traceback* techniques, however, require a large number of packets from the same source in order to isolate the sender. Along with several other researchers, developed a hash-based IP traceback system, the Source Path Isolation Engine (SPIE). SPIE represents the only known scalable solution that can trace a single IP packet to its source, even if it was transformed (tunneled, NATed, fragmented, etc.) in flight.

Through the use of Bloom filters, SPIE-enabled routers can efficiently maintain a sliding history of packets they have forwarded in the recent past. By recursively inspecting packet histories at each router backwards along the packet's path to the destination, SPIE is able to determine the path traversed by any arbitrary, recently-received IP packet.

1999–2000 **Active networking** – The promise of active networking has proven difficult to achieve in routing protocols. While the ability to continually describe custom forwarding paths for specific classes of traffic is attractive, designing a secure, scalable, and robust routing protocol is no small task. Hence, operators are loathe to adjust tuning parameters in operational networks, let alone replace routing protocols.

Helped design and implement the Flexible Intra-AS Routing Environment (FIRE), an extensible routing protocol that enables class-based routing through the use of multiple forwarding tables, constructed by downloadable routing algorithms using user-defined metrics. These algorithms build forwarding tables based upon link-state metrics collected using a shared, secure distribution protocol. FIRE frees traffic engineers to focus on routing algorithms by alleviating the burden of developing a distribution protocol.

HEWLETT-PACKARD RESEARCH LABS

1995–7 **Distributed application management** – Over the course of three summers, assisted in the design and implementation of a Model-Based Reasoning system for distributed application management, PROMISE. Modeled distributed applications using a novel inference language that allowed the expression of performance dependencies between components of a distributed system. Performance monitoring and control services enabled application management at the infrastructure (CORBA, DCE) level. In addition to service modeling, was responsible for network monitoring and configuration, as well as graphical user interfaces for model visualization.

NASA LEWIS (GLENN) RESEARCH LABS

1994 **Monte-Carlo simulation** – Designed and implemented Monte-Carlo simulations of spacecraft coating degradation during low-earth orbit due to high atomic-oxygen fluence, resulting in order-of-magnitude performance improvements over previous simulations, with no loss of accuracy. The physical phenomena resulting in decay occurs with infinitesimal probability, forcing traditional simulations to run for days before producing statistically significant results. By leveraging probability distributions, was able to dramatically decrease the number of runs required for convergence.

References

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Additional references available upon request.